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Technical Yearbook 2007/8

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LEAD THE WAY TOYOTA

JANUARY 2007 – DECEMBER 2007

contents

A technical guide for wine producers

Foreword

An area where a great deal more research will have to be done in the next few years, is how to deal with climate change throughout the Winelands, from Upington through to the border of the Eastern Cape.

While everybody has theories and worst-case scenarios, this is something which will have to be dealt with in a sober and scientific manner, taking into account what has been done in other winegrowing regions of the world and seeing how those scenarios impact on the domestic market.

This is an international problem which requires an international solution and integrated research will be necessary to find ways of overcoming it. It will have an ongoing impact on this industry and we have to gear ourselves to ensure that any negative effects are countered at an early stage.

Depending on what the future holds, water restraints may become more stringent, we will have to look seriously at how we improve, conserve and use that precious resource.

Another area gaining momentum, particularly in markets in the western world, is the issue of the carbon footprint. This will also have to be addressed in the same way as global warming, so that South African wineries are at the forefront of development for this new challenge.

We will also have to work together to ensure that if something new is learned it is communicated effectively to benefit everybody and in this regard this publication will strive to do just that. By combining all the most important research studies and articles we trust that these are used as reference material when grape growers and winemakers need to refresh their memories as they encounter challenges on their farms and in their cellars.

We have found that a great deal of research has been conducted over the past year, necessitating increasing the number of pages of this volume, while ensuring that the most relevant research is featured.

We trust that the season has been good to you so far and that for the upcoming harvest will be a memorable one and one filled with good products of the vine.

– Arnold Kirkby

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UNDER THE AUSPICES VinPro VIR KAAPSE WYNPRODUSENTE

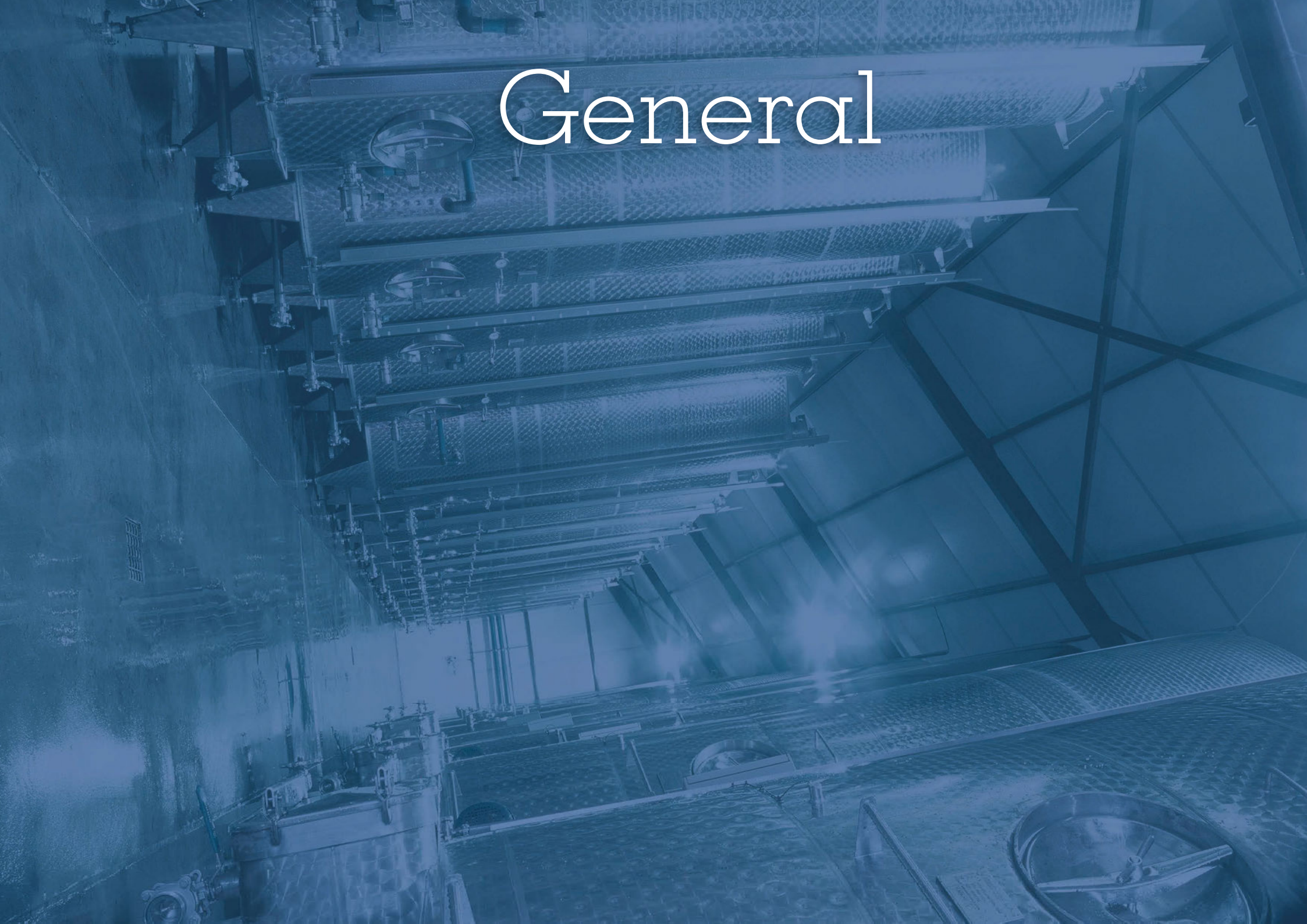
General

In the vineyard

In the cellar

"What's up in the vineyard & cellar" – Special series

"Wood in wine and wine in wood" – Special series



General

The cost of grape production and producer profitability – VinPro review

Gert van Wyk, VinPro Agricultural economist

Gert van Wyk

Introduction and review

It is a daunting task to make estimates or inferences with regard to the cost and profitability of wine grape farming. Farming enterprises differ in respect of the products they produce, the mix of red and white grapes, cultivar composition, production levels and quality obtained, producers' expectations regarding a realistic return for their efforts, prices paid by buyers, etc.

In recent years VinPro has conducted financial analyses in the various wine regions to determine the financial situation in which primary wine producers - in other words the producer who produces grapes for the wine industry - are likely to find themselves. This review, known as Production Plan, which has been conducted in conjunction with Winetech since last year, aims furthermore to provide an economic support service to producers and industry organisations, to increase the level of knowledge of financial management, and to determine industry averages and norms to be used in certain industry decisions.

During the 2005 review it was found that the total (201) number of participating producers realised an alarmingly low nett farming income (NFI) and that said profit margin had decreased by more than 50% since the previous vintage. From last year's (2006 vintage) analyses it seems, however, that the decrease in the industry average NFI continues and that it is now in all probability starting to take on critical dimensions. This, judging from the 2006 review which was conducted among 227 producers who represent approximately 18% of the total South African wine industry surface, in all 9 VinPro wine regions.

The assumption may be made that the majority of the participants have above-average managerial capabilities, follow scientific farming practices and are considered in many instances to be leading farmers in the various districts. In view of the aforegoing, as well as the fact that the size of the units that were evaluated is much bigger than the average (economies of scale undoubtedly resulted in a lower cost and capital structure), one can and should accept that profit margins are unlikely to increase if a bigger number of producers in the SA wine industry had to participate in the review.

Background to the calculations

• Cost of grape production / cost structure

In the production of grapes there are basically 3 important motivations that have a significant impact on profitability, viz:

- Cost per hectare
- Yield per hectare
- Cost per ton

The decrease in NFI continues and is beginning to reach alarming proportions.

Although it is generally accepted that the cost per hectare remains more or less the same, there will definitely be differences among vineyards - everything depends on the desired viticultural practices and requirements, as well as the product and price point for which production should take place, i.e. market oriented grape and wine production.

Large differences also occur among different geographic areas or districts in the industry i.r.o. the factors that influence total cost, the most prominent of which are certainly labour cost and yield per hectare.

The cost involved in the production of grapes - excluding the entrepreneur's remuneration, cost of land and interest - consists of the following components:

- Cash expenditure / Annual running costs
- Provision for replacement / Capital maintenance

Cash expenditure / Annual running costs

All cash expenses incurred in the year under review.

Provision for replacement / Capital maintenance

In the course of the production process machinery and implements are required, in addition to that which is bought annually for the production process. In due course of time tractors, equipment and other implements are no longer fit to be used. Even vineyards and buildings deteriorate and have to be replaced. The "deterioration" and "exhaustion" of these items form part of the cost of the production process.

Taking into account the fact that the purchase value of an item has to be recovered during its lifetime, as well as the vicissitude of inflation, sufficient provision has to be made for this. By using the principle 'provision for replacement', a larger amount is recovered than in the case of 'depreciation'. This addresses the issue of rectilinear depreciation to a certain extent and ensures that the going concern is maintained.

In the calculation of provision for replacement items are written off against replacement value:

Buildings	60 years
Vineyards	20 years
Movables / means of production	5-15 years

PRODUCTION COST FOR WINE GRAPES – COST AS RAND PER HECTARE (2006-HARVEST)

Weight	19.41%	19.97%	10.94%	8.36%	13.30%	3.28%	14.81%	9.93%	100.00%		
	Stb	Prl	Olif	Worc	Bkloof	KK	Rob	Orange	Average	Malm Irrigation	Malm Dryland
COST STRUCTURE	**R / ha**	**R / ha**	**R / ha**	**R / ha**	**R / ha**	**R / ha**	**R / ha**	**R / ha**	**R ha**	**R / ha**	**R / ha**
DIRECT COST											
FERTILISER	557	500	929	834	1,277	1,734	642	548	756	715	461
PESTICIDE CONTROL	1,594	907	913	1,335	1,429	811	1,250	725	1,176	1,553	1,052
HERBICIDE CONTROL	382	321	191	466	412	156	386	287	344	295	287
REPAIR & BINDING MATERIAL	294	112	69	60	55	257	11	71	116	61	46
Subtotal	**2,827**	**1,840**	**2,102**	**2,695**	**3,173**	**2,958**	**2,289**	**1,631**	**2,391**	**2,624**	**1,846**
LABOUR											
SUPERVISION	2,254	1,061	508	1,291	998	816	762	611	1,146	987	391
PERMANENT LABOUR	5,361	4,683	3,220	4,499	3,824	3,223	4,155	2,532	4,185	3,448	2,151
SEASONAL LABOUR	2,626	1,906	901	415	829	678	845	2,675	1,547	1,497	1,538
Subtotal	**10,241**	**7,650**	**4,629**	**6,205**	**5,651**	**4,717**	**5,762**	**5,818**	**6,878**	**5,932**	**4,080**
MECHANISATION											
FUEL	1,169	990	1,052	1,195	1,161	958	954	1,402	1,106	1,292	839
REPAIR AN SPARE PARTS	1,770	1,103	1,480	1,641	1,525	1,270	1,649	1,173	1,468	1,774	896
LISENCES AND ASSURANCE	315	209	365	401	321	315	261	398	308	277	156
TRANSPORT HIRED	84	238	153	46	83	91	42	171	122	24	233
Subtotal	**3,338**	**2,540**	**3,050**	**3,283**	**3,090**	**2,634**	**2,906**	**3,144**	**3,003**	**3,367**	**2,124**
FIXED IMPROVEMENTS											
REPAIR AND MAINTENANCE	671	559	262	371	514	321	658	191	497	146	91
ENSURANCE	245	82	211	251	146	152	124	675	218	154	83
Subtotal	**916**	**641**	**473**	**622**	**660**	**473**	**782**	**866**	**715**	**300**	**174**
GENERAL EXPENDITURES											
ELECTRICITY	626	712	958	980	1,048	906	994	368	803	775	247
WATER	677	324	1,514	796	116	1,396	578	729	647	458	70
RATES & TAXES	183	182	89	119	135	108	149	68	142	85	73
ADMINISTRATION	2,161	758	686	839	659	731	730	842	1,019	794	339
Subtotal	**3,647**	**1,976**	**3,247**	**2,734**	**1,958**	**3,141**	**2,451**	**2,007**	**2,612**	**2,112**	**729**
TOTAL CASH EXPENDITURES	**20,969**	**14,647**	**13,501**	**15,539**	**14,532**	**13,923**	**14,190**	**13,466**	**15,599**	**14,335**	**8,953**
PROVISION FOR RENEWAL	**6,040**	**4,967**	**6,785**	**5,650**	**5,499**	**5,996**	**5,639**	**5,950**	**5,733**	**5,816**	**3,696**
VINEYARDS	2,677	2,793	2,750	2,856	2,821	2,932	2,915	2,835	2,802	2,805	2,170
FIXED IMPROVEMENTS	738	437	573	585	526	501	494	365	538	553	265
LOOSE ASSETS	2,625	1,737	3,462	2,209	2,152	2,563	2,230	2,750	2,393	2,458	1,261
TOTAL EXPENDITURES	**27,009**	**19,614**	**20,286**	**21,189**	**20,031**	**19,919**	**19,829**	**19,416**	**21,332**	**20,151**	**12,649**
AVERAGE AREA PLANTED (HA)	**104.88**	**97.19**	**42.93**	**77.17**	**88.84**	**28.65**	**60.13**	**20.31**	**74.59**	**55.56**	**164.61**
AREA IRRIGATED (%)	**80.36**	**90.66**	**100.00**	**100.00**	**99.91**	**100.00**	**100.00**	**100.00**	**94.31**	**97.36**	**21.73**
AGE COMPOSITION (%)											
3 YEARS & YOUNGER	14.07	15.89	16.70	17.13	15.99	19.56	16.13	13.97	15.71	18.70	26.59
BETWEEN 4 & 7 YEARS	27.03	34.01	23.93	20.00	26.36	33.88	23.12	33.31	27.68	16.53	34.14
BETWEEN 8 & 15 YEARS	32.86	30.87	36.72	32.25	29.66	29.96	36.10	28.72	32.38	35.97	24.76
BETWEEN 16 & 20 YEARS	15.91	8.59	12.70	15.43	16.26	10.21	15.50	14.23	13.69	10.72	4.95
OLDER THAN 20 YEARS	10.13	10.65	9.96	15.19	11.74	6.40	9.15	9.77	10.55	18.08	9.55
AVERAGE YIELD (TON PER HA)	**7.30**	**9.49**	**23.92**	**16.34**	**18.14**	**17.07**	**14.06**	**30.07**	**15.34**	**11.88**	**6.14**
CASH EXPENDITURES (RAND PER TON)	**2,872**	**1,543**	**564**	**951**	**801**	**816**	**1,009**	**448**	**1,017**	**1,207**	**1,458**
TOTAL EXPENDITRUES (RAND PER TON)	**3,700**	**2,067**	**848**	**1,297**	**1,104**	**1,167**	**1,410**	**646**	**1,391**	**1,696**	**2,060**

The results

• Production cost

The industry average cash expenditure and total expenditure per hectare, except for Malmesbury, amounted to R15,599 and R21,332 respectively for the 2006 vintage. Variations of between R19,416/ha and R27,009/ha occurred among the said districts, while the industry average total expenditure amounted to R1,391 per ton. It varied from R646/ton for the Orange River to R3,700/ton in Stellenbosch.

Total labour cost amounts to 44% of the average annual cash expenditure, while fuel, cost of water (including electricity) and direct costs amount to a further 7%, 9% and 15% respectively... altogether 75% of the total cash expenditure.

• Profit (NFI)

Once the cost structure has been calculated, it is important to determine the production structure and profitability of participants.

In the calculation of the profitability of wine grapes two approaches may be taken, viz.

- The profitability of a specific production year
- The profitability of a specific vintage.

The results and findings in this report refer to the profitability of a specific vintage. The income that the crop will possibly realise is consequently partly estimated / expected income, but the actual cost of application regarding the particular vintage is in fact calculated. Experience has taught that the estimates

The average NFI iro the participants for the past 3 vintages

2004-HARVEST	Stb	Paarl	Olif	Worc	Bkloof	KK	Rob	Orange	Average	Malm
Average payment (R/ton)	4,684	4,104	1,383	1,768	1,817	1,643	1,991	–	2,383	3,135
Average yield (ton/ha)	7.12	7.57	21.96	17.05	17.19	18.66	15.19	–	13.11	6.04
Average income (R/ha)	**33,334**	**31,069**	**30,384**	**30,133**	**31,236**	**30,657**	**30,242**	**–**	**31,236**	**18,950**
Less	–									
Total cash expenditures (R/ha)	17,825	14,674	12,468	12,778	12,923	12,625	12,388	–	14,220	7,820
Gross Margin (R/ha)	**15,509**	**16,395**	**17,916**	**17,355**	**18,313**	**18,032**	**17,854**	**–**	**17,016**	**11,130**
Less	–									
Provision for renewal (R/ha)	5,079	4,249	5,419	4,704	4,589	4,815	4,821	–	4,780	2,952
Net farming income (R/ha)	**10,430**	**12,146**	**12,497**	**12,651**	**13,724**	**13,217**	**13,033**	**–**	**12,236**	**8,178**

2005-HARVEST	Stb	Paarl	Olif	Worc	Bkloof	KK	Rob	Orange	Average	Malm
Average payment (R/ton)	3,999	3,145	1,159	1,932	1,708	1,598	1,891	851	1,916	2,489
Average yield (ton/ha)	6.88	9.11	20.72	13.78	15.41	16.18	13.89	26.63	13.79	6.68
Average income (R/ha)	**27,537**	**28,646**	**24,014**	**26,640**	**26,313**	**25,855**	**26,258**	**22,671**	**26,424**	**16,635**
Less										
Total cash expenditures (R/ha)	19,208	14,515	13,307	15,770	14,091	13,779	13,523	12,379	15,010	9,613
Gross Margin (R/ha)	**8,329**	**14,131**	**10,707**	**10,870**	**12,222**	**12,076**	**12,735**	**10,292**	**11,414**	**7,022**
Less										
Provision for renewal (R/ha)	5,746	4,881	6,492	5,722	5,216	5,740	5,749	6,128	5,633	3,990
Net farming income (R/ha)	**2,583**	**9,250**	**4,215**	**5,148**	**7,006**	**6,336**	**6,986**	**4,164**	**5,781**	**3,032**

2006-HARVEST	Stb	Paarl	Olif	Worc	Bkloof	KK	Rob	Orange	Average	Malm
Average payment (R/ton)	3,681	2,623	1,170	1,869	1,660	1,429	1,826	883	1,763	2,039
Average yield (ton/ha)	7.30	9.49	23.92	16.34	18.14	17.07	14.06	30.07	15.34	9.01
Average income (R/ha)	**26,860**	**24,905**	**27,990**	**30,541**	**30,113**	**24,383**	**25,658**	**26,545**	**27,043**	**16,907**
Less										
Total cash expenditures (R/ha)	20,969	14,647	13,501	15,539	14,532	13,923	14,190	13,466	15,599	11,644
Gross Margin (R/ha)	**5,891**	**10,258**	**14,489**	**15,002**	**15,581**	**10,460**	**11,468**	**13,079**	**11,444**	**5,263**
Less										
Provision for renewal (R/ha)	6,040	4,967	6,785	5,650	5,499	5,996	5,639	5,950	5,733	4,756
Net farming income (R/ha)	**-149**	**5,291**	**7,704**	**9,352**	**10,082**	**4,464**	**5,829**	**7,129**	**5,711**	**507**

of producers and cellars are sufficiently accurate. The advantage of earlier processing, using an estimated income, is that the results of the analyses may be applied to planning and budgeting for the new production year.

Time value of money and delayed payments to producers are certainly some of the most important factors that are creating serious cash flow problems in the current economic climate. It is impossible to calculate the impact thereof in this review, seeing that all participants receive their income at different stages.

To determine the production structure the total surface planted to vines is considered, also age distribution, expected payment per ton, production per hectare and the expected income per hectare.

Profit or NFI is calculated as the difference between the total income and total production cost, i.e.: PROFIT (NFI) = TOTAL INCOME - TOTAL EXPENDITURE (Before interest / cost of land, tax and entrepreneur's remuneration.)

From the above it was obvious that the average NFI decreased by more than 50% from the 2004 to the 2005 vintage. This was due mainly to a sharp decrease in red wine prices, the more horizontal movement of white wine prices, smaller crops in certain districts, as well as the fact that the total costs increased. Although the 2006 analyses indicated some improvement i.r.o. NFI in certain districts, mainly due to larger crops / higher yield per hectare and the fact that said areas had a bigger percentage of white wine grapes, the average NFI for the industry continued to show a decrease.

With the 2004 analyses the average annual cash expenditure and total expenditure amounted to 46% and 61% respectively of the total income. This ratio deteriorated to such an extent that it amounted to 58% and 79% respectively according to the 2006 analyses. As a guideline for economically sustainable production, the average gross income and NFI should have realised R34,032 and R12,700 per hectare respectively. (Including interest / cost of land and entrepreneur's remuneration.) None of the districts evaluated last year managed to come near these figures.

As in all industries the wine industry and primary producer are also subject to increasing input costs, fluctuating climatological conditions as well as price fluctuations. Income does not increase at the same rate, however, and since the 2004 vintage the total income per hectare has in fact decreased. These circumstances naturally cause producers to find their cash flow under severe pressure and their profitability being constantly eroded. Profit margins, if any, make insufficient provision to meet exceptional capital obligations.

It will not be possible to meet additional obligations such as land tax, increased minimum wages, ongoing increases i.r.o. fuel prices, water levies, the effect of steep increases in excise tax, etc. and it is without any doubt clear that 'smaller' farming units will be the most severely affected. The smaller the unit, the more expensive the cost and capital structure, with the accompanying negative impact on the profitability of that business, if there is no compensation by obtaining high prices for the grapes.

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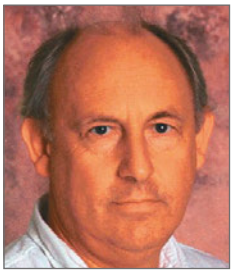
A perspective on climate change I. Causes and predicted effects

John Wooldridge, ARC Infruitec-Nietvoorbij, Stellenbosch



John Wooldridge

Introduction

In viticulture, consistent wine quality and style depend on reasonably stable environmental conditions. Of the many environmental factors that can affect both the grapevine and its product, climate (defined as the long-term average weather pattern experienced at a given locality, whereas weather is the state of the atmosphere at a particular time and place) is probably the most important. Because of its potential to affect populations and food security worldwide, climate change has been a controversial and sensitive topic over several decades. Climatologists fell into both anti and pro warming lobbies. Some pointed out that the variability in weather within seasons, from year to year, and from decade to decade, and the shortness of the period for which instrumented weather recordings are available are such that it is difficult to be certain about what constitutes a normal climate, let alone a climate change. This uncertainty and other apparent anomalies were used, on occasion, to obfuscate and trivialise the issue. Other observers cited early flowering and late leaf fall, species migrations, receding glaciers, insomniac bears, thawing permafrost, spells of unusually high temperature and rising sea levels as evidence of warming. From a viticultural viewpoint the conflicting viewpoints were confusing. Recently, however, evidence has accumulated to the point where there appears to be widespread consensus among climate researchers that warming is a reality. With that consensus, the controversy has largely shifted from the scientific to the political arena where it mainly concerns such issues as control and mitigation. On a more practical level the merits of such northern localities as Scotland, Alaska and Norway as sites for end-of-21st century premier dry white wine production, and of southern England for sparkling wines, are apparently being seriously debated.

Inherent in most discussions of climate change is the unspoken desire for conditions to remain the same. This is the most unlikely scenario of all. Change is integral to the functioning of a geologically and biologically active planet where climates function in an interactive system that includes the continents, oceans and atmosphere, and which now includes a new factor: man. Climates are driven by absorbed solar energy. This varies from place to place, with time of day and with season. Winds and storm systems are, in turn, atmospheric responses to shifting contrasts in temperature, pressure and moisture content, superimposed on global wind patterns created by convection and given direction by the earth's spin. Climates evolve, grading from the past, of which there is usually a record, through the present, which is recorded, into a future, which science attempts to predict, usually from ongoing tends. Prediction of long-term climate change usually entails the parallel running of large ensembles of models, each testing a slightly different set of assumptions (scenarios) concerning such variables as future fossil fuel use, emissions control and population dynamics. The output is a range of values which reflect the variation in the input scenarios. These become progressively more uncertain as the prediction period lengthens. There is considerable scope for error if the wrong scenario is followed. Ultimately, the best way to determine the accuracy of a model, and of the assumptions on which it is based, is to wait for the climate to evolve. In practice, assessments of likely changes in climate are usually based on historical trends (Midgley *et al.*, 2005. The models may themselves be tested and refined by running past climatic data for which the outcome is known. Knowledge of past climates is therefore extremely important, and ingenious methods for obtaining this information have been devised. Although organised instrumental recording only began in the mid to late 1800's, palaeoclimatic information dating far back into geological time can be derived from proxies such as tree rings, pollen, ice core data, cave carbonate deposits, isotopic ratios in sediments, and palaeogeographic reconstructions. Apart from providing data for model testing and predictive purposes, these studies provide evidence that certain aspects of global climate were, and remain, linked to geographic and other associated factors.

The aim of this article is to summarise and review the latest technical information on climate change. To enable this information to be interpreted in the widest possible context, the article begins with a discussion of how palaeogeographic factors have influenced the evolution of the present climate, and of how modern temperature and atmospheric compositions compare with those of past times.

Temperatures, past and present

The earth is currently passing through a warm interval in an ice age that began in the northern hemisphere around three million years ago (Mya) (Redfern, 2000). (An ice age may be described as a succession of periods of low temperature, associated with the expansion of glacial ice (glacials) and falling sea levels, alternating with shorter periods of relative warmth, receding ice cover and rising sea levels (interglacials)). Ice ages do not occur frequently. During the Phanerozoic, which dates back 542 My (Gradstein, *et al.*, 2004), and includes most of the time that complex, multicellular life has existed on earth, there have been only three ice ages and one cool spell. These occurred at irregular, roughly 140 My intervals. Once established, each ice age lasted for 50 My or more (Holmes, 1965; Global Warming Art(a)). The present northern ice age is therefore still in its early to mid-stages. Reconstructions of Phanerozoic palaeoclimates by Scotese (2002) suggest that global average

temperatures alternated between hot (22°C) and cold (12°C), with a mean of 17°C. By comparison the global average for the year 2000 was about 14.4°C (IPCC, 2007a). If reliable, these reconstructions show that the present interglacial temperatures are several degrees cooler than those which prevailed over most of the last half billion years.

Climatic zones, continental drift and the onset of the Cenozoic Ice age

The world's climatic zones form concentric belts, north and south of the equator. These belts are reflected in the Köppen-Geiger system of climate classification (Kottek *et al.*, 2006). The polar and cool temperate climatic belts expand during cooling phases, whereas the arid and warm temperate belts expand during warm phases. In the early Eocene (55 to 50 Mya), for example, tropical conditions extended 10 to 15 degrees of latitude poleward of their present limits. The belts do not change their relative positions. In contrast, the continents drift slowly across the latitudinal climatic belts and poles, driven by convection in the upper mantle. Climate is thus dependent on, *inter alia*, the shifting distribution of landmasses, relative to one another and to the climatic belts and, by extension, to the intervening ocean basins and current systems.

As is the case at present, past ice ages occurred at times when the distribution of the continental landmasses prevented effective heat transfer between the thermal equator and higher, cooler latitudes. The cooling that led to the present ice age began about 55 Mya when a warming trend was terminated by tectonic (mountain building) activity which raised the Himalayas and several other major mountain chains. The principal agents of heat distribution are ocean currents. That oceans should influence climates is unsurprising in view of the fact that around 70% of the earth's surface is covered by water. These currents change in pattern and strength in accordance with shifts in temperature and salinity, and with geographic changes such as occurred in the late Eocene, after 39 Mya, when the Drake Passage between South America and Antarctica began to open, permitting the development of a cold, circum-Antarctic current. Thus thermally isolated, the Antarctic continent, over which the south geographic pole is located, lost its vegetation and began to develop an ice sheet. This grew extensively around 33.5 Mya. By the end of the Oligocene, 23 Mya, glaciers were discharging into the sea, and water temperatures had fallen to the point where cold, saline bottom water was spiraling outwards and flowing northward into the Atlantic, Indian and Pacific oceans, all of which began to cool. Cooling continued as this newly established interpolar thermohaline (meridional overturning) circulation strengthened, relative to the pre-existing equatorial circulation (McCarthy & Rubidge, 2005). Since about 13 Mya, one of these currents (the Benguela) has upwelled along the west coast of southern Africa, brought to the surface by the prevailing offshore easterly winds which drive the warm surface waters westward. South Africa once received moisture-bearing winds from both the west and the east. However, because evaporation from cold water surfaces is slow, the effect of this upwelling current, combined with the blocking effect of the South Atlantic high pressure system on moisture-bearing winds from the west, was primarily that of inducing progressive aridification. This lead to the formation of the Kalahari Desert and the spread of savannah across the western interior. Further contributing factors were two episodes of uplift which, beginning 20 Mya, elevated the eastern side of the southern African subcontinent by 900 to 1150 m, as opposed to 250 m in the west (McCarthy & Rubidge, 2005). Thereafter, moisture from the Indian Ocean mainly precipitated over the uptilted eastern areas whilst the lower areas to the west fell into the associated rain shadow zone (McCarthy & Rubidge, 2005). Similarly, orographic rainfall over the north-south and west-east ranges of the Cape Fold Mountain Belt reduces the moisture content of air masses flowing into the interior of the southern Cape from the west and south (Midgley *et al.*, 2005).

Cooling of the northern hemisphere did not become significant until about 3.5 Mya, perhaps 15 My after Antarctica had frozen over. Again, the main triggering factor was geographic. This time it involved the closure, rather than the opening, of a seaway. This seaway, which separated the North and South American landmasses, became increasingly restricted as the Isthmus of Panama developed. Final closure terminated the latitudinal flow of warm equatorial Atlantic water into the Pacific, causing the temperature of the eastern north Pacific to decline. An additional effect of this closure was to direct warm equatorial Atlantic water, with its high overlying atmospheric humidity, into the north Atlantic, causing an increase in cloud cover and a higher ratio of reflected to absorbed solar energy (albedo). Precipitation fell as snow at high northern latitudes, further increasing heat reflection, and by 3.1 Mya glaciers had formed on the higher northern mountains. Regional cooling was exacerbated by rapid heat loss from the northern landmasses (land gains and losses heat faster than water) (Redfern, 2000). Between 3.0 and 1.6 Mya there were long periods of glacial advance and retreat and, at some point during this interval, the Arctic Ocean, which is largely landlocked, developed a perennial ice cover. Beneath the sea ice, dense, cold, highly saline water began to sink to the bottom and flow southward, drawing in warm Atlantic water behind it, thereby further strengthening the inter-polar thermohaline circulation. The northern continental ice sheets reached their greatest extent in the Pleistocene, 1.8 Mya to 11.5 thousand years ago (Kya) (Gradstein et al., 2004). Between the extremes of each cycle, of which there were at least four, climatic zones shifted by 20 to 30 degrees of latitude (2400 to 3200 km) (Redfern, 2000). These shifts presented the plant and animal populations with enormous evolutionary challenges, resulting in a number of species, including most of the cold-adapted giant mammals, becoming extinct. On at least one occasion, sufficient water was locked into the continental ice sheets that sea levels around southern Africa fell by up to 130 m, exposing the continental shelves, causing deep incision of watercourses and promoting increased aridity and dune formation. Dust carried by winds from unprotected surfaces to high altitudes blocked sunlight, leading to further cooling. Nevertheless, the mountains of the Western and Southern Cape remained glacier-free throughout the Pleistocene. In consequence, the landscapes and soils of the region did not benefit from the rejuvenating effects of glacial action, as on the higher-latitude northern continents, where fertile soils formed in mineral-rich parent materials derived from freshly ground rock. Neither did the region gain from the formation of lakes by glacial action.

Waning of the last glacial period

The last major glacial period peaked about 21 Kya, then receded, to be followed between 12.9 and 11.5 Kya by a short glacial period called the Younger Dryas. The Younger Dryas was remarkable for its rapid onset. Mean annual temperatures in Greenland and the UK decreased by 15°C and 5°C, respectively, below today's temperatures, apparently within a few decades. Recovery was even more rapid. Thus, although climate change is generally a slow process it may, on occasion, be extraordinarily fast. A wildcard in times of rapid global warming is disruption of the inter-polar thermohaline circulation by the release into the North Atlantic of large volumes of fresh water from rapidly melting continental ice sheets, such as could result from the melting of the Greenland ice cap, which may be approaching a stability threshold. Such disruptions have the potential to promote abrupt, but probably transient cooling at high northern latitudes, even in the face of a warming trend (Redfern, 2000). Paradoxically, exposure of the Arctic Ocean by melting of the sea ice could lead to sufficient evaporation, followed by precipitation as snow and the spreading of high-albedo snow and ice surfaces, to trigger the onset of another glacial period (Holmes, 1965). Other wildcards that could, perhaps, promote rapid change include the release of methane from warming permafrost, the sudden formation of methane gas from hydrates on the sea bed, and widespread changes in land use.

The Holocene: a warm interval

In contrast to the Pleistocene, the Holocene Epoch (11.5 Kya to present), which followed the Lower Dryas, was characterised by generally moderate temperatures, fluctuating around a slowly decreasing trend. By about 8 Kya berries of the wild European grape, which was native to an area which extended from Spain to the eastern Mediterranean and into parts of central Asia, and which occurred in humid forests and beside streams, were being harvested by foragers. By 5.5 to 5 Kya the grapevine had been domesticated. As recorded in the Domesday Book, vineyards were located in 46 places in southern England in the late eleventh century. Yet even within the Holocene there were climatic variations and, in southern Africa, the Holocene was characterised by wet and dry periods. Sea levels also fluctuated, by around 800 mm over the last 1000 years alone (Redfern, 2000). Perhaps the best known incident was the Little Ice Age, the latest of six Holocene cold spells (Mayewski *et al*., 2004), which lasted from the late 13th to the mid 19th Century, during which period winter fairs were held on the ice-covered River Thames. Investigation of oxygen isotope ratios in a 6.5 Ka stalagmite from a cave in the Makapansgat Valley of South Africa provided evidence that the Little Ice Age was not confined to the northern hemisphere, as was once thought (Lee-Thorp *et al*., 2001). During the later stages of the Little Ice Age temperatures in South Africa, Greenland and Antarctica were colder than at any time in the last half million years. The cause of the Little Ice Age is unclear. Theories include increased albedo from volcanic dust in the upper atmosphere, and reversion to CO_2-consuming scrubby woodland by cleared agricultural land following the partial depopulation of Europe during the Black Death pandemic, which commenced in the mid 1300's. A further theory holds that climate change reflects harmonics of an 11-year cycle in solar energy output (Perry & Hsu, 2000). These ideas remain controversial. From the foregoing it is apparent that the earth is currently passing through an interglacial period in an ice age. This ice age is a mainly a consequence of the way in which the continents and oceans are currently distributed. What the distribution of continents does not explain is why, within the present ice age, conditions have alternated between glacial periods and times of comparative warmth.

Glacial cycles and orbital factors

The larger scale (90 to100 Ky) glacial cycles observed in ice cores dating back over 400 Ka have been shown to correspond with cyclical changes in orbital eccentricity, and in the tilt and wobble of the earths' axis of rotation. These orbital changes, which were first calculated by the mathematician Milutin Milankovich (1879 to1958), caused periodic changes in the amounts of radiant solar energy which are received at the earth's surface. That these changes are small (0.1%), relative to the scale of the climatic responses they induce, suggests that the balance between glacial and interglacial states is delicately poised. Such a balance, where an ice age can be initiated or terminated by small changes in heat inflow, can only occur under circumstances in which the continents and oceans are in a suitable configuration. Principal elements in this present configuration are the positioning of the south geographic pole over the Antarctic continent, the thermal isolation of Antarctica in the Southern Ocean by circum-polar currents, and the position of the north geographic pole over the Arctic basin, with its limited circulation and extensive surrounding continental landmasses. Because the land masses surrounding the north geographic pole gain and lose heat faster than the waters of the southern ocean, the far northern hemisphere is more susceptible to rapid climate change than the southern hemisphere. That the earth currently, and perhaps atypically, possesses a number of high mountain ranges and cool elevated plateaus may be a further factor in the climate balance.

Contrasting future climates

Based on the orbital parameters known as Milankovich Cycles, and assuming an interglacial period of 10 to 12 Ky (20 Ky, according to Perry & Hsu., 2000), the earth should now be approaching the end of the Holocene warm phase and retreating into another 90 to 100 Ky glacial period (Redfern, 2000). Similarly, the solar output model of Perry & Hsu (2000) indicates that the earth should cool gradually over the next few centuries, though with occasional warmer periods. Given the slow rate of continental drift, the continents could remain in an ice age configuration for another 20 My or so (Redfern, 2000). However, in stark contrast to these predictions, a 2007 United Nations (UN) report asserts that, far from cooling, the earth will get warmer.

Recent findings on climate change

In February 2007, the UN Intergovernmental Panel on Climate Change (IPCC) published its fourth assessment report concerning the physical science basis of climate change (IPCC, 2007a). This was followed, in April 2007, by the IPCC report on climate change impacts (IPCC, 2007b). According to the UN News Centre (2007), IPCC (2007a) 'describes an accelerating transition to a warmer world'. The summary of the scientific report states that warming of the climate system is now 'unequivocal', as is evident from observations of increases in global average air and ocean temperatures, widespread melting of snow and ice, and a rising global average sea level. Average northern hemisphere temperatures between 1950 and 2000

were 'very likely' (>90% likelihood) higher than any other 50-year period in the last 500 years, and 'likely' (>66%) the highest in the last 1.3 Ky. Over the 100-year period from 1906 to 2005, global average temperatures warmed by 0.74°C, with an uncertainty range of 0.56 to 0.92°C, as compared with 0.6°C for the 100-year period that preceded the previous (third) IPCC assessment report. Over the past 50 years the linear warming trend has averaged 0.13°C (range 0.10 to 0.16°C) per decade); almost twice the average rate for the last 100 years. During 11 of the 12 years from 1995 to 2006, surface temperatures ranked amongst the 12 warmest years since 1850 (IPCC, 2007a). There is 'very high confidence' (9 out of 10 chance) that recent warming is strongly affecting biological systems, such as the shift toward earlier timing of spring events like leaf unfolding, and to poleward and upslope shifts in the ranges of plant and animal species (IPCC, 2007b).

What caused this warming? Clearly, the process, and its driver(s), must have been, and continue to be, sufficiently powerful to over-ride the cooling effects of orbital factors and of the ice age configuration of the continents, oceans and currents. The answer, according to IPCC (2007a), is that most of the increase in global average temperatures since the mid 20th century is 'very likely' due to the presence of unnaturally high concentrations of certain gases in the atmosphere, and that these (greenhouse) gases are produced by, or as consequences, of human activities. That the same conclusion was reached a century ago by Svante Arrhenius illustrates the way in which ideas arise, evolve through a testing process and finally gain general though qualified support.

The greenhouse effect and its main drivers

The temperature at which a balance between the amount of heat which the earth receives from the sun, and that which it returns to space (either through reflection or as black body radiation from the upper atmosphere) is reached is controlled by the imprecisely but evocatively named greenhouse effect. The principle active component, or driver, of the greenhouse effect is carbon dioxide (CO_2), although methane, nitrous oxide and twenty-odd other gases are also involved, as is water vapour (IPCC, 2007a). These are known as greenhouse gases.

The overloaded carbon cycle

Carbon dioxide moves between the atmosphere, biosphere, soils and oceans in a process known as the carbon cycle. This cycle contains geological and biological mechanisms able to remove carbon from the atmosphere and store it in a variety of forms, some more permanent than others. However, present rates of CO_2 production exceed the absorption capacity of the carbon cycle. Further, carbon removal is slowed by warming, which suppresses CO_2 absorption by the oceans and accelerates oxidation of carbon-rich organic materials in soils, as does excessive tillage, and deforestation. (A recent report indicates that deforestation in the tropics drives warming to a greater extent than deforestation at high latitudes.) A consequence of the progressive disabling of these carbon removal processes, and of further additions from fossil fuels is that the CO_2 concentration of the global atmosphere will increase with time. A temperature increase of about 0.2°C per decade is projected for the next two decades. Had aerosol and greenhouse gas concentrations been kept constant at the year 2000 levels warming would still proceed, but at 0.1°C per decade (IPCC, 2007a, b). According to IPCC (2007b), unavoidable warming due to past greenhouse gas emissions will amount to a further 0.6°C by the end of the century. Depending on the assumptions made, best estimates for temperatures in the last decade of the 21st century lie between 1.8°C (with a likely range of 1.1 to 2.9°C) and 4.0°C (2.6 to 6.4°C) warmer than for the last decade of the 20th century (IPCC, 2007a). After greenhouse gas concentrations eventually stabilize, warming will continue for centuries due to the long time periods needed to remove excess CO_2 from the atmosphere.

Greenhouse gases and fossil fuels

Carbon dioxide concentrations in the global atmosphere increased from a pre industrial (about 1750) value of approximately 280 parts per million (ppm) to 379 ppm in 2005 (IPCC, 2007a), a rise of 35%. Ice core data show that the atmospheric CO_2 concentration in 2005 was higher than at any time in the last 650 Ky, during which period natural CO_2 concentrations ranged from 180 to 300 ppm. The annual atmospheric CO_2 growth rate was 1.9 ppm per year between 1995 and 2005, as opposed to 1.4 ppm per year for the period 1960 to 2005. The main source of this CO_2 was, and continues to be, the combustion of fossil fuels (coal, oil and gas), with land use change making a significant additional contribution (IPCC, 2007a). Combustion of fossil fuels returns carbon that had been safely stored in the crust for tens of millions of years to the atmosphere as CO_2, thereby adding to the carbon already active in the carbon cycle. That the bulk of the CO_2 now entering the atmosphere came from fossil fuels is confirmed by similarities in their isotopic signatures. Methane, a bi-product of agriculture and of fossil fuel use, increased in abundance from a pre industrial global atmospheric concentration of around 715 parts per billion (ppb) to 1774 ppb in 2005, relative to a natural range of 320 to 790 ppb for the last 650 Ka. Corresponding pre-industrial and 2005 values for nitrous oxide, which is also produced by agriculture, were 270 and 319 ppb, respectively (IPCC, 2007a).

Fossil fuel production and consumption, and CO_2 production from fossil sources, have increased appreciable over the past few years, driven by the energy demands of a world population that, in 2000, was virtually double that in 1960 and almost 20 times that in the year 1000. World coal production increased from 4941 million short tons (MST) in 1999 to 6079 MST in 2004, an increase of 23%. Therein lies the essence of the problem. China, with about 20% of the world's population, increased her coal output by 58% over the same period (Energy Information Administration, 2004a). Likewise, the world per-capita increase in CO_2 emissions from the consumption and flaring of fossil fuels between 1999 and 2004 was 9.8%, whilst that for China was 57% (Energy Information Administration, 2004b). This continued generation of greenhouse gases, which adds fossil carbon to the already overloaded carbon cycle, will probably mean that climate changes during the 21st century will be more severe than in the 20th century. To stabilize atmospheric CO_2 concentrations at 450 ppm it may be necessary to reduce cumulative carbon emissions over the 21st century by an average of about 27%. Since biofuels are synthesized from atmospheric CO_2 by photosynthesis and, therefore, do not increase the total carbon in the carbon cycle, as do fossil fuels, the substitution of bio for fossil fuels should be an immediate priority.

Apparent anomalies in the relationship between warming and CO_2

An apparent contradiction to the concept that greenhouse

gases induce warming (best estimate for warming due to doubling of the atmospheric CO_2 concentration is 3°C (IPCC, 2007a)) is that, despite the current upward trend, modern atmospheric CO_2 concentrations are close to the lowest that they have been over the past 500 My. Analyses of proxy data by several authorities, notably Berner & Kothavala (2001) are compared in Global Warming Art(b). Collectively, these data show that atmospheric CO_2 concentrations have varied considerably over the last half billion years. The overall trend has nevertheless been downward, from 15 to 20 times present concentrations in the Cambrian, around 500 Mya, to five to eight times present levels by 100 Mya. By 20 Mya, CO_2 concentrations had probably reached pre industrial levels (< 300 ppm). The spread of grasses may have contributed to the later stages of this downward trend (Retallack, in McCarthy & Rubidge, 2005). Significantly, the only occasion when both temperatures and CO_2 concentrations resembled those of the present day was the Carboniferous, around 300 Mya. During that geological period massive amounts of carbon were drawn from the atmosphere by green plants and buried in subsiding coal swamps. Carbon was also extracted from the atmosphere and water by phytoplankton, and incorporated into sediments which, on heating, gave rise to oil and gas. Phytoplankton proliferated, probably like modern algal blooms, at times when warm, shallow seas were widespread, as in the Jurassic. It is this carbon that was safely stored in coal, oil and gas that is being returned to the atmosphere by human activity.

A further apparent anomaly is that, rather than increasing CO_2 concentrations driving (forcing) the warming process, as is now the case, Antarctic ice core data shows that, before human activities became a factor, the CO_2 increases lagged behind the warming, in one case by around 800 years (Caillon *et al.*, 2003). At the time of the associated deglaciation, some 238 Kya, CO_2 was therefore not the driving force. The belated increase in atmospheric CO_2 concentration was probably due to a warming-induced release of CO_2 from the southern ocean. Glacial retreat in the northern hemisphere did not begin until about 6 Ka later, which implies that CO_2 forcing lagged slightly behind and amplified orbital forcing, in accordance with greenhouse theory.

Effect of aerosols

It is 'likely' that the warming induced by the greenhouse gases would have been greater had temperature increases not been moderated by aerosols such as sulphate, organic carbon, black carbon (soot), nitrate, dust and other pollutants which reflect sunlight back into space (IPCC, 2007a). These particulate materials enter the atmosphere through human activities, and also through natural events like volcanic eruptions. Where high concentrations of aerosols and of particulates, such as volcanic ash, are injected into the atmosphere, the cooling effect may be both rapid and marked, as depicted in the nuclear winter scenario, and as was observed after volcanic eruptions in 1963, 1982 and 1991. Industrial aerosol emissions supposedly contributed to a cool spell between 1940 and 1970. Because aerosols tend not to linger in the atmosphere, their effects are short lived whereas greenhouse gases persist for many decades. The effects of aerosols tend to be concentrated in areas downwind of the source of pollution. Pollutants from high altitude aircraft have a greater cooling effect than those that originate near the surface.

Global effects of climate change

If greenhouse gas emissions continue at the present, accelerating, rate, further warming will occur, leading to changes in the climate system that will 'very likely' be greater in the 21st than in the 20th century. During the 21st century, temperature changes will be smallest over the Southern Ocean. Warming is 'likely' to be greatest over land at high northern latitudes. In fact, over the last century, average Arctic temperatures have increased at almost twice the average global rate. In the North Atlantic, overturning, a part of the normal thermohaline circulation process, is 'very likely' to weaken by 25% (range zero to 50%) by 2100. It is nevertheless 'very unlikely' (<10% likelihood) that the thermohaline circulation will undergo a major change during the 21st century (IPCC, 2007a). Outside the tropics, storm tracks will move poleward, and it is 'very likely' that extreme weather events (heat waves, heavy precipitation, strong winds) will increase in frequency as a consequence of the additional energy in the atmosphere. Mid-latitude westerlies have actually been strengthening since the 1960's in both hemispheres. The water vapour content of the atmosphere has also increased in recent years, over both land and ocean. This increase, which is roughly equivalent to the greater water holding capacity of warm, relative to cool air, implies that rainfall will increase globally, though not uniformly. Some areas will receive more rain, whilst others will become drier. Precipitation is 'likely' to increase at high latitudes, and to decrease at low latitudes. It is also 'likely' that the overall area affected by droughts will increase.

One of the main effects of the warming that has already taken place was that global sea levels rose at an average rate of 1.8 mm (1.3 to 2.3 mm) per year over the period 1961 to 2003. Between 1993 and 2003 the rate was even faster, at 3.1 mm (2.4 to 3.8 mm) per year. Over the course of the 20th century, sea levels rose by an estimated 17 mm (12 to 22 mm). Estimated increases in sea level for the decade 2090 to 2099, relative to 1980 to 1999, vary between ranges of 18 to 38 mm, and 26 to 59 mm. These increases mostly stem from thermal expansion induced by the fact that, since 1961, average temperatures in the global ocean have increased to depths of at least 3000 m, and the ocean has been absorbing over 80% of the heat added to the climate system IPCC (2007a). This warming will exacerbate the melting of sea ice in both hemispheres. Sea ice may have almost vanished from the Arctic by the latter part of the 21st century (IPCC, 2007a).

Current projections suggest that the Antarctic continental ice sheet, which contains over 70% of the worlds fresh water and has an average temperature of -49°C, is likely to remain too cold to permit extensive melting (though the sea ice will certainly diminish). The continental ice cover could even gain mass through increased snowfall, provided that loss through accelerated glacial outflow does not occur (IPCC, 2007a; UN News Centre, 2007). In contrast, the Greenland ice sheet will continue to contract, contributing to rising sea levels. During the last interglacial, around 125 Kya, average polar temperatures were 3 to 5°C higher, and global sea levels 4 to 6 m above present sea level. Since sea levels are unaffected by the melting of sea ice, most of this increase in sea level can be ascribed to melt water from the continental ice sheets. In the lower Pliocene, before cooling began in the northern hemisphere, sea levels were even higher, which is why a whale skeleton and shark teeth have recently been found in a Tuscany vineyard about 29 Km from the present coastline.

Effects of climate change in the Western Cape

As documented in a report compiled for the Provincial Government of the Western Cape (Midgley *et al.*, 2005), trends observed at various Western Cape weather stations over the past 30 to 40 years include an increased frequency of strong low-pressure systems in March, April and May, and a decreased incidence in June, July and August. The incidence of strong high pressure systems between September and February also increased, enhancing the risk of hot, dry berg winds and veld fires. Minimum temperatures for the periods December to March, and July to September, tended to increase. Maximum temperatures showed warming trends in January, May and August. Mean annual maximum and minimum temperatures also showed significant warming trends.

Trends in precipitation are complex. In southern Africa the long term trend (1900 to 2005) has been toward reduced rainfall (IPCC, 2007a). In the Western Cape specifically, rainfall over the mountainous areas has either remained the same or trended upward, whereas the rainfall trend for the lowlands has been slightly negative. The already-steep rainfall gradient between mountains and lowlands has therefore intensified. It remains to be seen whether the drying experienced in the south west of the Cape will reach 10% by the mid 21st century as predicted by Issar (2003).

Projections for the future mirror the trends of the past few decades. The interior and eastern areas of the Western Cape will probably experience increased precipitation in late summer, particularly over mountains. This is consistent with the view that the atmosphere will contain more moisture, leading to increases in both orographic (precipitation from air masses that are forced to rise by mountains) and convective (precipitation from heat-driven buoyant air masses) rainfall. In the south west of the Western Cape, early and late winter precipitation will decrease. The period during each winter when cold fronts bring rain, to the Western Cape will therefore shorten. Since warming tends to increase the incidence of extreme weather events, it is likely that the frequency of cut-off low pressure systems, with their steep gradients, strong winds, heavy rainfall and associated flooding will increase, notably in autumn and spring.

Minimum, maximum and mean temperatures are likely to rise everywhere except the Antarctic continent. By 2050, temperatures in coastal areas and inland of the coastal mountains of South Africa will be warmer by around 1.5°C, and 2 to 3°C, respectively. The likely effects of climate change will be increased aridity and loss of biodiversity, particularly in the western lowlands of the Cape. These changes will promote a progressive migration of species to moister areas to the east (Midgley *et al.*, 2005).

From the arguments, observations and projections presented thus far it will be evident that the world in irrevocably set on a warming course, and that other aspects of climate, notably rainfall, will also be affected.

References

Berner, R.A. & Kothavala, Z., 2001. GEOCARB III: a revised model of atmospheric CO_2 over Phanerozoic time. Am. J. Sci. 301, 182-204.

Caillon, N., Severinghaus, J. P., Jouzel, J., Barnola, J. M., Kang, J. & Lipenkov, V.V., 2003. Timing of atmospheric CO_2 and Antarctic temperature changes across Termination III. Science, 299, 1728-1731.

Energy Information Administration, 2004a. Internation energy annual, 2004. Table 2.5, World Coal Production, 1980-2004. Accessed 6 March 2007. http://www.eia.doe.gov/pub/international/iealf/table25.xls

Energy Information Administration, 2004b. Internation energy annual, 2004. Table H.1cco2 World Per Capita Carbon Dioxide Emissions from the Consumption and Flaring of Fossil Fuels, 1980-2004. Accessed 6 March 2007. http://www.eia.doe.gov/pub/international/iealf/tableh1cco2.xls.

Global Warming Art a. Image: Phanerozoic climate change Rev. png. Accessed 5 April 2007. *http://www.globalwarmingart.com/wiki/Image:Phanerozoic_*Climate_Change_Rev_png

Global Warming Art b. Image: Phanerozoic carbon dioxide. Accessed 4 April 2007. *http://www.globalwarmingart.com/wiki/Image:Phanerozoic_*Carbon_Dioxide_png

Gradstein, F.M., Ogg, J.G. & Smith, A.G., 2004. A geologic time scale 2004. Cambridge University Press, Cambridge.

Holmes, A., 1965. Principles of physical geology. Thomas Nelson, London.

Intergovernmental Panel on Climate Change, 2007a. Fourth Assessment Report, Working Group I. Climate change 2007: the physical science basis. Summary for policymakers, corrections of 5 February 2007. Accessed 9 February 2007. *http://www.ipcc.ch/spm2Feb07.pdf*

Intergovernmental Panel on Climate Change, 2007b. Fourth Assessment Report, Working Group II. Climate change 2007: climate change impacts, adaptation and vulnerability. Summary for policymakers, 6 April 2007. Accessed 10 April 2007. *http://www.ipcc.ch/spm6avr07.pdf*

Issar, A.S., 2003. Climate changes during the Holocene and their impact on hydrological systems. Cambridge University Press. Cambridge.

Kottek, M., J. Grieser, C. Beck, B. Rudolf, and F. Rubel, 2006. World Map of the Köppen-Geiger climate classification updated. Meteorol. Z., 15, 259-263.

Lee-Thorp, J.A., Holmgren, K., Lauritzen, S.-E., Linge, H., Moberg, A., Partridge, T.C., Stevenson, C. and Tyson, P.D., 2001. Rapid climate shifts in the southern African interior throughout the mid to late Holocene. *Geophysical Research Letters* 28, 4507-4510.

McCarthy, T. & Rubidge, B., 2005. The story of earth and life. A southern African perspective on a 4.6-billion-year journey. Struik Publishers, Cape Town.

Mayewski, P.A., Rohling, E.E., Stager, J.C., Karlén, W., Maasch, K.A., Meeker, L.D., Meyerson, E.A., Gasse, F., van Kreveld, S., Holmgren, K., Lee-Thorp, J., Rosqvist, G., Rack, F., Staubwasser, M., Schneider, R.R. & Steig, E.J., 2004. Holocene climate variability. Quaternary Research 62, 243-255.

Midgley, G.F., Chapman, R.A., Hewitson, B., Johnston, P., De Wit, M., Ziervogel, G., Mukheibir, P., Van Niekerk, L., Tadross, M., Van Wilgen, B.W., Kgope, B., Morant, P.D., Theron, A., Scholes, R.J. & Forsyth, G.G., 2005. A status quo, vulnerability and adaptation assessment of the physical and socio-economic effects of climate change in the Western Cape, Report to the Western Cape Government, Cape Town, South Africa. CSIR Report No. ENV-S-C 2005-073, Stellenbosch.

Perry, C.A. & Hsu, K.J., 2000. Geophysical, archaeological, and historical evidence support a solar-output model for climate change. Proc. National Academy of Sciences of the United States of America 93, 12433-12438.

Redfern, R., 2000. Origins. The evolution of continents, oceans and life. Weidenfeld & Nicolson, London.

Scotese, C.R., 2002. Paleomap project: climate history. Accessed 26 February 2007. *http://www.scotese.com/climate.htm*

UN News Centre, 2 February 2007. Evidence is now unequivocal' that humans are causing global warming. Accessed 5 February 2007. http://www.un.org/apps/news/story.asp?NewsID=21429&CR=climate&Cr1=change

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A perspective on climate change II. Implications for global and South African viticulture

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Summary

The world is experiencing a warming trend. Warming may bring benefits to cool viticultural regions, but is likely to create problems in areas that are already close to the upper temperature limits for the cultivars and wine styles concerned. In these cases, relocation, or replacement with varieties that are better adapted to the higher temperatures will be necessary if it is not possible to ameliorate the effects of climate change through management practices. Because of its southern location, long coastline, rugged topography and multiplicity of potential alternative vineyard sites, Cape viticulture is likely to survive climate change better than some intra-continental wine producing regions in the northern hemisphere.

Introduction

As outlined by in the previous article in this series, (Wooldridge, xxxx), world climates are currently changing. Temperatures are slowly increasing everywhere, except for Antarctica. In the Western Cape, rainfall is likely to become less reliable, leading to a probable increase in aridity, notably in the lowlands. Of the many environmental factors that potentially affect grapevine performance, and the characteristics of must and wine, climate is probably the most important, mainly because it affects grapevine physiology (Hunter & Bonnardot, 2004). The aim of this article is, therefore, to speculate on the effects of the climate changes discussed by Wooldridge (xxxx) on global and South African viticulture.

Effects of climate on grapevines and wine

Since most biochemical reactions are temperature sensitive, any change in the temperature regime experienced in a defined viticultural area (a 'terroir', according to Vaudour & Shaw, 2005) is likely to affect the grapevine, the juice and the wine. Cultural practices such as canopy management may help to maintain quality (Hunter *et al*., 2004; Marais, 2005a,b,c). In other cases, chiefly in areas in which temperatures are already close to the upper temperature limits for the existing wine grape varieties, such forms of mitigation (IPCC, 2007b) are likely to be of limited effectiveness necessitating more drastic actions, such as the substitution of tolerant for sensitive varieties. Such major changes are nevertheless likely to alter the character of the products of a region, possibly eliciting negative responses from established consumers.

Within limits, warming promotes earlier ripening, an increased rate of vegetative growth in grapevines, and a faster progression through the phenological stages. However, a survey of the worlds' viticultural areas indicates that, provided the climate is sufficiently warm to ripen any given grape variety, wine quality will decrease with increasing warmth and length of summer (Jackson & Lombard, 1993). This stems from the fact that such physiological processes as photosynthesis, sugar and potassium accumulation, and organic acid formation proceed at near peak efficiencies at day temperatures between 20°C and 30°C (Hunter & Bonnardot, 2004), although some processes have different ranges. A consequence is that the effects of both supra and of suboptimal temperatures will be negative, as in the case of anthocyanin synthesis where colour is impaired at temperatures below and above an optimum range of 17 to 26°C. In Pinotage, colour was darker, and total antioxidant capacity (TAC) higher, in wine from trellised vines from cool, than from warm regions (De Beer et al., 2006). These researchers also found that Pinotage from bush vines was darker, with slightly higher TAC, than from trellised vines, perhaps because the bush canopies were denser and more shaded than the trellised canopies. Wine quality in white varieties, such as Sauvignon blanc, is also significantly affected by canopy density and management (Marais, 2005a). Flavour and aroma components are temperature sensitive. Conradie & Bonnardot (2004) showed that, in Sauvignon blanc wines from the Breede River Valley, aroma intensity was higher from cool than from the warm localities whereas, in Cabernet Sauvignon from the cool vineyards possessed a marked grass character, although berry character dominated under warm conditions. In Cabernet Sauvignon from the warm vineyards, both berry character and aroma intensity were lower in sandy, relative to clay soils. In the Stellenbosch area, Sauvignon blanc grapes from warm vineyards were harvested 14 days earlier than from cool vineyards (Conradie & Olivier, 2004). Whereas the warm vineyard wines were characterised by tropical fruit character, irrespective of soil conditions, the wines from the cooler vineyards differed according to the water holding capacity of the soil, the wetter soils producing wines with fresh vegetative character, while the drier soils produced wines in which cooked vegetative character was dominant. Temperature and soil/water effects are therefore linked. Water stress, a common accompaniment to heat, low humidity and wind in Cape vineyards, tends to promote early ripening, but reduces yield and berry weight, and may suppress malic acid formation (Jackson & Lombard, 1993). Aspects of grape berry ripening and juice composition that are affected by temperature and stress include colour, acidity, sugar content, sugar to acid ratio and the type and abundance of flavour and aroma compounds. In Sauvignon blanc, Marais (2005a) identified two dominant wine styles: a cool climate style, characterised by a green pepper/asparagus, and a fruity/tropical warm climate style. The most likely effect of warming is that, although sugar content will increase rapidly, acidity may be lost through respiration while the winemaker is waiting for flavours to develop. Wines produced from such grapes will tend to be unbalanced; high in alcohol, with too little acidity to produce the desired freshness (Jones & Davis, 2000; Jones, 2004). Wines produced in Western Europe during 2003, when temperatures over a three month period were 3 to 5°C higher than normal were, indeed, high in alco-

hol, low in acidity and highly variable in quality (Seguin & De Cortazar, 2005). Soluble solids also increase with temperature (Jackson & Lombard, 1993). Temperature regimes in which warm (20 to 25°C) days contrast with cool (10 to 15°C) nights tend to be more beneficial than warm day and warm night temperature regimes, mainly because acidity is retained while pH declines (Jackson & Lombard, 1993; Hunter & Bonnardot, 2002, 2004). The trend over the past 50 years has nevertheless been for cold days and cold nights to become less frequent while hot days and nights have become more frequent, as have heat waves. Since day and night temperatures have increased by the same amount, the diurnal temperature range has remained the same, although there is variability between regions (IPCC, 2007a). High temperatures have a variety of negative effects. Both photosynthesis and rate of dry matter accumulation in grapevine decrease with increasing temperature and at ≥ 35°C are much reduced, which is consistent with findings that dry matter accumulation correlates with average rate of photosynthesis. In Chenin blanc and Chardonnay, one of the first effects of heat stress is reduced stomatal conductance (Sep lveda & Kliewer, 1986). Reduced photosynthesis at high temperatures may nevertheless be less a consequence of stomatal closure than of enzymatic malfunction (Ferrini et al., 1995).

Defining precisely what constitutes an ideal vineyard climate is the subject of ongoing research. Hunter & Bonnardot (2002, 2004) differentiated between viticultural regions in terms of their relative abilities to promote physiological functioning (photosynthesis) on the basis of climate profiles compiled from pre and post véraison hourly mean temperature, relative humidity and wind speed data. Hours during which these parameters fell within optimal range limits for photosynthesis (between 09:00 and 16:00 (Greenwich Mean Time + 2); temperature range 20 to 25°C; relativity humidity 60 to 70%; wind speeds ≤ 4 m/s) were compared with hours above or below these limits. Marked variation in the number of hours available for optimal physiological functioning was observed between regions and between areas within regions. Hunter & Bonnardot (2002, 2004) hold that mean climatic data alone are insufficient to understand climatic impacts on grapevine physiology, and provide little information about conditions within the canopy and between the vine rows. In Chenin blanc, light intensity within the canopy appears to be a critical quality determining factor, necessitating careful management to maximize indirect radiation around the ripening berries (Marais, 2005b).

Implications of climate change for global viticulture

The effects of increased temperatures are likely to be positive in some viticultural areas. Jones et al. (2005) evaluated international vintage ratings to determine the effects of climate on vintage rating over time and showed that the warming trend between 1950 and 1999 was linked with an increase in vintage quality and a decline in year-to-year variation. This trend could not be fully explained by the improvements in viticultural methods that occurred during the same period. The cooler climatic regions benefited most from the warming, some improving by 13 points on a 100 point scale per 1°C rise in temperature (Jones, 2004). The impacts of climate change were nevertheless not uniform across all regions and varieties, with poleward locations potentially becoming more suitable for grape growing and wine production, as in the case of England where growing conditions in the past decade have been likened to those of the 13th century (Jones, 2004). The early 13th century was the latter part of a period of anomalously warm weather (possibly associated with a peak in solar activity) that preceded the Little Ice Age. In Bordeaux, France, Jones & Davis (2000) showed that incoming solar radiation levels during the budburst interval were positively linked with vintage quality, probably by promoting higher rates of photosynthesis. Further, an increase in the number of days with maximum temperatures over 30°C during floraison and véraison promoted early growth and full maturation.

Other viticultural areas will not benefit from global warming. Deleterious effects will be most marked in regions that are already at, or near, the optimum temperature range for the cultivars grown, and for the wine styles produced. Wine production will become more difficult under these changed circumstances, and may even prove unviable. White *et al.* (2006) consider that periods of extreme heat, amongst other factors, will result in premium wine production in the United States becoming largely restricted to parts of the west coast, the Northwest and the Northeast, with a potential 81% decrease in premium wine grape production by the end of the 21st century. In Australia, temperatures in most viticultural areas are predicted to increase by between 0.3 and 1.7°C by 2030 and 0.8 to 5.2°C by 2070 (Webb *et al.*, 2005). Although these increases, coupled with higher atmospheric CO_2 concentrations, could conceivably enable larger crops to be ripened, the increases will have negative effects on grape production and quality within regions. Costs, in terms of diminished quality, will range from zero to 25% by 2030, and there will be a progressive southward shift in suitability within each region, value decreasing in the inland, and increasing in the more southerly regions.

The longevity of vineyards makes them particularly sensitive to climate change, and problems could arise if heat intolerant varieties are planted in localities which, though cool at present, grow warmer within the production life of the vineyard. Wine grape varieties that are likely to be negatively affected by warming include Pinot Noir and Riesling, which perform well in coastal valleys and in such cool areas as the slopes of Burgundy in France and the Rhine River Valley in Germany. In South Africa, aroma intensity and overall quality are higher in cool, relative to warm localities in Sauvignon blanc (Conradie & Bonnardot, 2004), implying that this variety must also be regarded as sensitive to warming. More emphatically, Marais (2005a) maintains that Sauvignon blanc should only be grown in selected cool localities. On the other hand, some varieties, such as Cabernet Sauvignon, and Zinfandel, seem to tolerate a range of climatic conditions.

On a wider agricultural basis, the potential for food production at mid to high latitudes should increase with increasing local average temperature over a range of 1 to 3°C, then decrease. Even small increases in temperature (1 to 2°C) may reduce production at low latitudes and in seasonally dry areas (IPCC, 2007b).

Implications of climate change and viticulture in South Africa

South Africa will not be exempt from the effects of climate change. However, whereas changes in surface temperature over the period 1970 to 2004 ranged from 0.2 to 1.0°C over most of South Africa, the corresponding increase for much of Spain and France was 1.0 to 2.0°C (IPCC, 2007b). If projections that Antarctica will remain too cold to permit much

melting of the continental ice sheet are accurate (IPCC, 2007a), it seems likely that the cold circum-Antarctic ocean circulation and climate will remain more stable than the climates of the continental land masses of mid to high northern latitudes. Recent reports of warming of the southern ocean surface water, and of destabilization and thinning of ice sheets leading to increased rates of glacial discharge from the Antarctic continent have been refuted by IPCC (2007a) which states that, although the Antarctic sea ice varies in extent between seasons and localities, there is no statistically significant trend. This is consistent with the absence of a warming trend in average atmospheric temperatures across the region. In contrast, average annual sea ice coverage in the Arctic has shrunk by 2.7% (2.2 to 3.3%) per decade since 1978 (IPCC, 2007a).

Much will depend on the effect of warming on the strength and latitude range of the southern Hadley convection cell which, in summer, brings dry, descending, deflection- (Coriolis) driven air masses to the Cape in the form of the South Easter, and which generates the South Atlantic and Indian Ocean high pressure cells. Strengthening of the Hadley Cells could reduce the extent to which the South Hadley Cell moves north in winter. This would lead to an increased percentage of the storm front-bearing north westerly winds of the south convective Ferrel Cell (which parallel the southern edge of the Hadley Cell), following a more southerly path in winter, resulting in an increased percentage of cold fronts missing the Western Cape altogether. Patterns of evaporation and precipitation over the oceans are already changing, as is evidenced by the fact that the ocean water at mid to high latitudes is becoming fresher, while that at low latitudes is becoming more saline (IPCC, 2007a). By mid century, water availability in dry regions at mid latitudes is projected (with 'high confidence', ie, about an 8 out of 10 chance) to decrease by 10 to 30% (IPCC, 2007b)

According to Jones (2004), projected temperature changes for the northern hemisphere are greater than for the southern hemisphere. Of the world's wine grape growing regions, South Africa will be the least affected by warming (Portugal will be the most seriously affected). This is reassuring in view of the fact that, because viticulture is already taking place close to South Africa's southern coastline, the option of relocating further south, as in parts of Australia, is limited. Because of the rugged topography of the Western Cape, there is the possibility of moving to higher land where, because air temperature decreases by almost 1°C per 100 m increase in altitude, cooler conditions may be expected as, in some of the higher locations, may an increased incidence of orographic cloud. The relationship between altitude and height is nevertheless affected by a range of physical parameters, such as aspect, slope and the varying effects of topography on slope (Wooldridge & Beukes, 2005). Based on data from the Coastal Region of the Western Cape, Myburgh (2005a) found that February mean temperatures declined at the rate of 0.5°C per 100 m increase in altitude, but increased by around 0.6°C for every 10 km increase in distance from the ocean. The strategy of moving to higher ground suffers from the obvious disadvantages that the higher the land, the less there is of it, the greater the difficulty of access, working, and water supply, and the greater the risk of erosion and, perhaps, fire. Since the viticultural areas of the Cape are located in fairly close proximity to the ocean with its locally pronounced cooling effect, temperatures will continue to be more moderate than those experienced in intra-continental settings, as in Europe and on the North American continent. Vineyards along the Orange River near Upington, where summer temperatures frequently exceed 40°C, are nevertheless likely to be severely affected by warming

Offsetting the relative coolness induced by the closeness of the Western Cape to the ocean is that the vineyards of the Western Cape are situated 10 or more degrees of latitude closer to the equator than most of the European viticultural areas. Because light intensity increases with decreasing latitude, they therefore receive appreciably higher levels of incoming solar radiation, even though summer day length is shorter (Jackson & Lombard, 1993; Wooldridge & Beukes, 2005). The range of climatic variables between, and even within individual wine producing regions and areas may nevertheless be wide (Conradie *et al.*, 2002; Hunter & Bonnardot, 2002; 2004). This is especially the case in the Western and Southern Cape where there are three distinct gradients (Midgley *et al.*, 2005). These are: an increase in aridity from south to north, a west to east transition from winter to summer rainfall, and a tendency for the higher mountain ranges to receive more rain in summer than the surrounding lowlands. A further variable is that the rugged topography conferred by the fold mountain ranges, and by the contrasting, erosion-resistant sandstone and soft, easily weathered shale formations has led to the formation of a variety of habitats, each with its own mesoclimate. These habitats range from low to high altitude, from north to south facing, from cool to hot, and from arid to relatively moist. They also differ in terms of distance from the coast, and exposure to coastal and other winds. The soils also vary, from sandy or gravelly with low water holding capacities, to clay soils with high water holding capacities. In some areas, such as the Breede River Valley (Conradie & Bonnardot, 2004) and Stellenbosch (Conradie & Olivier, 2004) wine style is significantly affected by soil form, as well as by climate.

The Elgin, Grabouw and Villiersdorp areas, amongst others, may soon become too warm for effective commercial apple production (Midgley *et al., 2005*). In these areas it is likely that deciduous fruit having high chilling requirements will progressively give way to stone fruit, fruit of Mediterranean origin or wine grapes. Viticulture is also likely to expand in the cooler areas inland of Cape Agulhas, wherever suitable land is available without impinging on the fynbos. Only 149 000 ha of land in South Africa are suitable for the production of high quality wines under present conditions (Knight, 2006). Since 101 607 ha were occupied by wine grapes in 2005 (SAWIS, 2006), there would seem to be little room for expansion. This situation will worsen if sections of the land identified by Knight (2006), which mainly occupies a narrow strip along the Western Cape coast and between Natures' Valley and East London, are rendered unusable for viticulture by construction or by erosion. Coastal erosion could become a problem in some areas towards the end of the 21st century (IPCC, 2007b).

The climatic variable that will probably have the greatest influence over the future success of viticulture in the Western Cape in a warming world is the amount, intra-seasonal timing, geographic distribution and season-to-season variation in rainfall. In lowland areas, where water is already limiting, any further reduction may result in too little water being avail-

able to the vine to offset heat stress induced by stomatal closure, and to prevent desiccation of the berries. Stomatal closure is likely to offset any gains that may result from the increased CO_2 content of the atmosphere (CO_2 fertilization). Increases in summer rainfall, as predicted by Midgley *et al.* (2005) could also have negative effects on quality, notably through berry enlargement, elevated juice pH and acid content, and reduced anthocyanins due to shading induced by prolonged growth (Jackson & Lombard, 1993; Jones & Davis, 2000). In practice, the Western Cape is already experiencing water shortages, exacerbated by increasing demands from burgeoning urban populations. In view of the fact that irrigation currently uses 60% of South Africa's available water (Midgley *et al., 2005*), these demands are likely to be acceded to. Seasons in which the region's largest storage dams fill to capacity are infrequent, and may become even less frequent in future. The new Berg River dam will ease short term supply problems but by 2015 demand is again expected to exceed supply. Another factor to take into account in low rainfall areas is the progressive tendency for salts to accumulate in the root zone, particularly where evaporation rates are high, water quality marginal and drainage poor.

Possibly offsetting the negative effects of water shortage is the refined state in South Africa of the science and practice of maximising wine grape yield and quality per unit of irrigation water consumed. Myburgh (2005b), for example, showed that a single supplementary irrigation event when the berries were pea sized was sufficient to sustain vegetative growth and yield in Sauvignon blanc and Chenin blanc in the Stellenbosch district, provided that the soils were well prepared. Indeed, further irrigation, during berry ripening, tended to reduce wine quality in both cultivars (Myburgh, 2006). Under semi-arid conditions irrigation may be used to influence berry size (Myburgh, 2003). Irrigation techniques that suppressed berry size in Chenin blanc resulted in wine with more intense fruitiness and less intense bottle ageing character than grapes from treatments which increased grape size Marais (2005c). Small Chenin blanc berries seem to contain higher concentrations of flavourants and their precursors than large berries (Marais, 2005b).

A cause for cautious optimism is legislation that permits the removal of alcohol from wine. Further, because consumer tastes change over time, it is probable that tastes will adapt in step with warming-induced changes in wine character and style (Schulz, in Joubert, 2006), provided that the changes continue to be gradual. It is reassuring that, during the late Cenozoic interglacial periods, with their rising or high sea levels and elevated atmospheric CO_2 concentrations, conditions in the Western Cape appear to have been equable, with moderate to warm temperatures, reasonable rainfall and an extensive vegetation cover. In contrast, conditions during glacial periods were far less pleasant. Falling sea levels were accompanied by relatively low temperatures, reduced rainfall, incision of watercourses, exposure of the continental shelves, increased aridity, the spread of the Kalahari desert, and abundant wind-driven dust (Hendey, 1983). Of these alternatives, a limited amount of warming is preferable to a reversion to glacial conditions. Taking optimism to its limit, it is conceivable, though unlikely, that the premises on which the warming predictions are based are erroneous, and that the current warming trend will prove to be nothing more than a late stage of recovery from the Little Ice Age. Only time will tell.

From a demarcation viewpoint it is pertinent that, in many old-established European viticultural areas, zoning is strongly influenced by historical factors and by tradition, and may even be based on a single qualitative variable (Vaudour & Shaw, 2005). If warming renders the designated geographic area less able to produce the traditional product, a new area will need to be designated, established and marketed. However, because history and tradition will have no predictive, or market value in the warmer world, it will be necessary to develop a new set of criteria before rezoning can take place. In contrast, zoning in South Africa is based on records of observations and measurements, mostly obtained from research programs of which some span decades. The ongoing nature of this process means that any changes in demarcation or cultural practice that further climate change may make desirable will be routine in terms of research and development.

On balance, given the diversity of potential viticultural sites, efficient irrigation, an excellent knowledge base concerning viticulture and soils and a field research based system of demarcation, fine wines are likely to be produced in South Africa for a considerable time to come. If, perhaps, on a reduced scale. Expansion into new areas, and the development of new methods, will certainly lead to a considerably increased diversity of wine styles. Carbon efficiency in wine production may soon become a plus point in marketing, as is the environmentally-friendly treatment of winery wastes. As ever, the key to success in changing times will be timely adaptation, based on sound information. (Low adaptive capacity was identified by IPCC (2007b) one of the main reasons why Africa is amongst the most vulnerable continents to climate change). Relative to viticulture, the future of the wider deciduous fruit industry in the Cape is less certain (Midgley *et al.*, 2005). Fruit trees are generally less resilient than grapevines. Of greater importance, though, is the reality that temperatures across much of the Western Cape are already too high to enable sensitive fruit varieties to obtain sufficient winter chill, and to reliably break dormancy, without chemical stimulation. Future prosperity, particularly for apple growers, growers will therefore hinge on the ability of plant breeders to produce cultivars which have ultra-low winter chill requirements (Labuschagné *et al.*, 2000), are resistant to sunburn. The trees must also be able to produce economic yields of high quality fruit on limited amounts of water of less than optimal quality due to increased salinity.

References

Conradie, W.J. & Bonnardot, C., 2004. Effects of soil and climate on wine style in the Breede River Valley of South Africa: Sauvignon blanc and Cabernet Sauvignon. Proc. Joint International Conference on Viticultural zoning, 15-19 November 2004, Cape Town, South Africa, p. 282-287.

Conradie, W.J. & Olivier, M.P., 2004. Effects of soil and climate on wine style in Stellenbosch: Sauvignon blanc. Proc. Joint International Conference on Viticultural zoning, 15-19 November 2004, Cape Town, South Africa, p. 522-525.

Conradie, W.J., Carey, V.A., Bonnardot, V., Saayman, D. &

van Schoor, L.G., 2002. Effect of different environmental factors on the performance of Sauvignon blanc grapevines in the Stellenbosch/Durbanville districts of South Africa. I. Geology, soil, climate, phenology and grape composition. S. Afr. J. Enol. Vitic. 23, 78-91.

De Beer, D., Joubert, E., Marais, J., van Schalkwyk, D. & Manley, M., 2006. Climatic region and vine structure: effect on Pinotage wine phenolic composition, total antioxidant capacity and colour. S.Afr. J. Enol. Vitic. 27, 151-166.

Ferrini, F., Mattii, G.B. & Nicese, F.P., 1995. Effect of temperature on key physiological responses of grapevine leaf. Am. J. Enol. Vitic. 46, 375-379.

Hendey, Q.B., 1983. Cenozoic geology and palaeogeography of the fynbos region. In: H.J. Deacon, Q.B. Hendey & J.J.N. Lambrechts (eds). Fynbos palaeoecology: a preliminary synthesis. South African National Scientific Programmes Report No. 75, December 1983, p. 1-20.

Hunter, J.J., Volschenk, C.G., Marais, J. & Fouché, G.W., 2004. Composition of Sauvignon blanc grapes as affected by prevéraison canopy manipulation and ripeness level. S. Afr. J. Enol. Vitic. 25, 13-18.

Hunter, J.J. & Bonnardot, V., 2002. Climatic requirements for optimal physiological processes: a factor in viticultural zoning. In: Proc. 4th International Symposium on Viticultural Zoning, 17-20 June 2002, Avignon, France, p. 553-565.

Hunter, J.J. & Bonnardot, V., 2004. Methodology to assess vine cultivation suitability using climatic ranges for key physiological processes: results for three South African regions. In: Proc. Joint International Conference on Viticultural zoning, 15-19 November 2004, Cape Town, South Africa, p. 203-213.

Intergovernmental Panel on Climate Change, 2007a. Fourth Assessment Report, Working Group I. Climate change 2007: the physical science basis. Summary for policymakers, corrections of 5 February 2007. Accessed 9 February 2007. http://www.ipcc.ch/spm2Feb07.pdf

Intergovernmental Panel on Climate Change, 2007b. Fourth Assessment Report, Working Group II. Climate change 2007: climate change impacts, adaptation and vulnerability. Summary for policymakers, 6 April 2007. Accessed 10 April 2007. http://www.ipcc.ch/spm6avr07.pdf

Jackson, D.I. & Lombard, P.B., 1993. Environmental management practices affecting grape composition and wine quality – a review. Am. J. Enol. Vitic. 44, 409-430.

Jones, J.V., 2004. Making wine in a changing climate. Geotimes 50, 22-27.

Jones, G.V. & Davis, R.E., 2000. Climate influences on grapevine phenology, grape composition, and wine production and quality for Bordeaux, France. Am. J. Enol. Vitic. 51, 249-261.

Jones, J.V., White, M.A., Cooper, O.R. & Storchmann, K., 2005. Climate change and global wine quality. Climatic Change 73, 319-343.

Joubert, L., 2006. WOSA News, Tuesday 03 October. Winemaking in a warmer world. Accessed 22 February 2007. http://www.wine.co.za/news/news.aspx?NEWSID=9141&Source=Newsfeed

Knight, F., 2006. A macro scale analysis of the vineyard production potential of the RSA. Wynboer (November), 71-74.

Labuschagné, I.F., Schmidt, K., Louw, J.H. & Sadie, A., 2000. Breeding low-chill requiring apple cultivars (*Malus x domestica* Borkh.) in South Africa. Acta Hort. 538, 281-288.

Marais, J., 2005a. Factors affecting Sauvignon blanc wine quality: a South African perspective. Wynboer Technical Yearbook 2005/6, 67.

Marais, J., 2005b Effect of berry size, sunlight exposure and ripeness on Chenin blanc wine quality. Wynboer Technical Yearbook 2005/6, 53-54.

Marais, J., 2005c. Can the shelf life of Chenin blanc wine be enhanced? Wynboer Technical Yearbook 2005/6, 88-90.

Myburgh, P.A., 2003. Response of *Vitis vinifera* L. cv. Sultanina to level of soil water depletion under semi-arid conditions. S. Afr. J. Enol. Vitic. 24, 16-24.

Myburgh, P.A., 2005a. Effect of altitude and distance from the Atlantic Ocean on mean February temperatures in the Western Cape Coastal Region. Wynboer Technical Yearbook 2005/6, 49-52.

Myburgh, P.A., 2005b. Water status, vegetative growth and yield responses of *Vitis vinifera* L. cvs. Souvignon blanc and Chenin blanc to timing of irrigation during berry ripening in the Coastal Region of South Africa. S. Afr. J. Enol. Vitic. 26, 59-67.

Myburgh, P.A., 2006. Juice and wine quality responses of *Vitis vinifera* L. cvs. Souvignon blanc and Chenin blanc to timing of irrigation during berry ripening in the Coastal Region of South Africa. S. Afr. J. Enol. Vitic. 27, 1-7.

Midgley, G.F., Chapman, R.A., Hewitson, B., Johnston, P., De Wit, M., Ziervogel, G., Mukheibir, P., Van Niekerk, L., Tadross, M., Van Wilgen, B.W., Kgope, B., Morant, P.D., Theron, A., Scholes, R.J. & Forsyth, G.G., 2005. A status quo, vulnerability and adaptation assessment of the physical and socio-economic effects of climate change in the Western Cape, Report to the Western Cape Government, Cape Town, South Africa. CSIR Report No. ENV-S-C 2005-073, Stellenbosch.

SAWIS, 2006. SA wine industry statistics nr 30. South African wine industry information and statistics, Paarl.

Seguin, B. & De Cortazar, I.G., 2005. Climate warming: consequences for viticulture and the notion of 'terroirs' in Europe. Acta Hort. 689, 61-65.

Sep Iveda, G. & Kliewer, W.M., 1986. Stomatal response of three grapevine cultivars (*Vitis vinifera* L.) to high temperature. Am. J. Enol. Vitic. 37, 44-52.

Vaudour, E. & Shaw, A.B., 2005. A worldwide perspective on viticultural zoning. S. Afr. J. Enol. Vitic. 20, 106-115.

Webb, L.B., Whetton, P.H. & Barlow, E.W.R., 2005) Impact on Australian viticulture from greenhouse induced temperature change. Accessed 16 February 2007. http://www.mssanz.org.au/modsim05/papers/webb_lb.pdf

White, M.A., Diffenbaugh, N.S., Jones, G.V., Pal, J.S. & Giorgi, F., 2006. Extreme heat reduces and shifts United States premium wine production in the 21st century. PNAS 103, 11217-11222.

Wooldridge, J. & Beukes, H., 2005. Radiant solar energy interception in the Western Cape. Wineland (February), 66-68.

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In the vineyard

The influence of Calcium and Magnesium soil applications on the performance and Potassium uptake of *Vitis vinifera* L. cvs. Cabernet Sauvignon and Cabernet franc in the Paardeberg area

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Introduction

The effect of fertilisation on the performance of grapevines has been researched by various authors (Somers, 1975; Conradie & Saayman, 1989a; Conradie & Saayman, 1989b; Ruhl, Fuda & Treeby, 1992; Jackson & Lombard, 1993; Champagnol,1994; Etourneaud, 1996; Gallego, 1999; Daverede & Garcia, 2000). One of the aspects of grapevine performance is the quality of juice and wine produced by the grapevine. According to Boulton (1980a) one of the most important factors in the determination of the quality of juice and wine is pH. However, the pH of wines is sometimes excessively high, throughout the world and also in the Western Cape, and little is known about the extent to which this may be influenced by fertilisation. This investigation studied the effect of different Ca and Mg soil applications on the performance of Cabernet Sauvignon and Cabernet franc and the pH of juice, specifically with regard to soils of granitic origin, inter alia, since there are indications that granite as mother material may give rise to high K levels in plants (Wooldridge, 1985).

MATERIAL AND METHODS

Experimental procedure

A random block design field trial, with 12 factorial treatment combinations and two repetitions, was conducted in the Paardeberg area on each of two farms, viz. Meerlus and Kersfontein. According to Siegfried (1993) Paardeberg forms part of the Malmesbury Batholith, which consists of six different granites and a quartz porphyry gangue. The farms were selected on the premise that the mother material of the soils would most likely be granite. On Meerlus a five-year-old Vitis vinifera L. var. Cabernet franc vineyard, grafted onto 99 Richter (Vitis Berlandieri var. Las Sorres x Vitis rupestris var. du Lot) was used, and on Kersfontein a

Table 1: The effect of different Ca and Mg soil applications on the pH and electric resistance (RS) of soil from two farms (Meerlus and Kersfontein) in the Paardeberg area, one year after application.

Main effects	Soil treatment	Soil depth (cm)	Meerlus	Kersf.	Treatment[1] Average	Meerlus	Kersf.	Treatment[1] Average	Meerlus	Kersf.	Treatment[1] Average
			$pH_{(H2O)}$			$pH_{(KCl)}$			R_S (ohms)		
Soil treatment	Control	0-30	5.67	5.52	**5.60 b**	5.11	4.71	**4.91 b**	2346	1488	**1917 a**
	$CaSO_4$		5.31	5.27	**5.29 c**	5.09	4.60	**4.85 b**	795	1064	**929 c**
	$Ca(OH)_2$		6.41	6.01	**6.21 a**	6.08	5.45	**5.77 a**	1745	1849	**1797 ab**
	$MgSO_4$		5.68	5.33	**5.50 bc**	5.21	4.56	**4.88 b**	1609	1288	**1448 b**
Farm	Average[1]		**5.99 a**	**5.31 b**	5.65	**5.51 a**	**4.70 b**	5.11	**1624 a**	**1422 a**	1523
		30-60	5.39	5.36	**5.37 a**	4.75	4.79	**4.77 a**	1586	1506	**1546 a**
	$CaSO_4$		5.22	5.21	**5.21 a**	4.84	4.67	**4.76 a**	1043	859	**951 b**
	$Ca(OH)_2$		5.37	5.29	**5.33 a**	4.88	4.52	**4.70 a**	1695	1681	**1688 a**
	$MgSO_4$		5.25	5.36	**5.30 a**	4.80	4.67	**4.73 a**	963	722	**842 b**
Farm	Average[2]		**5.32 a**	**5.29 a**	5.31	**4.79 a**	**4.69 a**	4.74	**1232 a**	**1191 a**	1212
		60-90	4.86	5.54	**5.20 a**	4.24	4.82	**4.53 a**	1616	1703	**1660 a**
	$CaSO_4$		5.12	5.39	**5.26 a**	4.35	4.62	**4.49 a**	1130	1131	**1131 b**
	$Ca(OH)_2$		4.98	5.42	**5.20 a**	4.36	4.65	**4.51 a**	1608	1569	**1588 a**
	$MgSO_4$		4.85	5.60	**5.23 a**	4.38	4.72	**4.55 a**	791	745	**768 c**
Farm	Average[2]		**4.90 b**	**5.55 a**	5.23	**4.11 b**	**4.92 a**	4.52	**1286 a**	**1257 a**	1272

[1] Treatment averages for the same measured characteristic and depth, followed by the same letters, do not differ significantly at P≤0.05.

[2] Farm averages for the same measured characteristic and depth, followed by the same letters, do not differ significantly at P≤0.05.

Table 2: The effect of different Ca and Mg soil applications on the extractable Ca, Mg and K of soil from two farms (Meerlus and Kersfontein) in the Paardeberg area, one year after application.

Main effects	Soil treatment	Soil depth (cm)	Meerlus	Kersf.	Treatment average	Meerlus	Kersf.	Treatment average	Meerlus	Kersf.	Treatment average
			Ca ($cmol_c\ kg^{-1}$)			Mg [2, 3] ($cmol_c\ kg^{-1}$)			K [2] ($cmol_c\ kg^{-1}$)		
Soil treatment	$CaSO_4$	0-30	1.41	1.34	**1.37 b**	**0.45 b**	**0.45 bc**	0.45	**0.25 c**	**0.36 a**	0.30
	$Ca(OH)_2$		2.46	2.00	**2.23 a**	**0.30 cd**	**0.20 d**	0.25	**0.27 bc**	**0.31 ab**	0.29
	$MgSO_4$		2.60	2.17	**2.39 a**	**0.38 bc**	**0.32 bcd**	0.35	**0.25 c**	**0.32 ab**	0.29
			1.17	0.94	**1.05 c**	**1.07 a**	**1.17 a**	1.12	**0.26 c**	**0.28 bc**	0.27
Farm	Average [4]		**2.00 a**	**1.52 b**	1.76	0.55	0.54	0.55	**0.25 b**	**0.32 a**	0.29
Soil treatment	$CaSO_4$	30-60	2.13	1.93	**2.03 a**	**0.55 c**	**0.53 c**	0.54	**0.19 a**	**0.25 a**	0.23
	$Ca(OH)_2$		1.83	2.03	**1.93 a**	**0.54 c**	**0.58 c**	0.56	**0.22 a**	**0.30 a**	0.26
	$MgSO_4$		1.77	1.59	**1.68 a**	**0.48 c**	**0.47 c**	0.47	**0.19 a**	**0.29 a**	0.24
			1.50	1.35	**1.43 a**	**1.08 b**	**1.60 a**	1.34	**0.18 a**	**0.28 a**	0.23
Farm	Average [4]		**1.75 a**	**1.78 a**	1.77	0.66	0.80	0.73	**0.20 b**	**0.28 a**	0.24
Soil treatment	$CaSO_4$	60-90	1.47	1.51	**1.49 a**	**1.22 abc**	**0.95 cd**	1.08	**0.18 a**	**0.19 a**	0.19
	$Ca(OH)_2$		1.62	1.57	**1.59 a**	**1.04 bcd**	**0.95 cd**	0.99	**0.18 a**	**0.19 a**	0.19
	$MgSO_4$		1.74	1.65	**1.56 a**	**0.97 bcd**	**0.85 d**	0.91	**0.19 a**	**0.19 a**	0.19
			1.55	1.81	**1.68 a**	**1.24 ab**	**1.49 a**	1.37	**0.17 a**	**0.20 a**	0.18
Farm	Average [4]		**1.44 b**	**1.72 a**	1.58	1.12	1.06	1.09	**0.18 a**	**0.19 a**	0.19

[1] Treatment averages for the same measured characteristic and depth, followed by the same letters, do not differ significantly at P≤0.05.
[2] Averages for the same depth, followed by the same letters, do not differ significantly at P≤0.05.
[3] As a result of the significant interaction between main effects, farm and treatment averages could not be compared statistically.
[4] Farm averages for the same measured characteristic and depth, followed by the same letters, do not differ significantly at P≤0.05.

five-year-old Vitis vinifera L. var. Cabernet Sauvignon vineyard, grafted onto 101-14 Mgt. (Vitis riparia x Vitis rupestris). Two profile pits on each of Meerlus and Kersfontein were used for the typing of the soils.

Treatments

Although three canopy management and four chemical soil applications took place, this report is concerned only with the latter. Soil applications of 5 t ha-1 CaSO4.2H2O and equivalent quantities of Ca(OH)2 and MgSO4.7H2O, with a control treatment of no applications, were given once during February 1998 (two weeks before the harvest). These treatments were scattered evenly over the surface and worked into the soil with spades to a depth of 10 cm, thereafter 20mm irrigation was given.

Sampling

One year after the application of the chemical soil treatments, an auger was used to take soil samples for each site at 0-30 cm, 30-60 cm and 60-90 cm depths. These samples were analysed for applicable characteristics using standard analytical methods of the Soil Science Department at Stellenbosch University. Soil descriptions were given of two profile pits made in each vineyard.

Bunches were counted and weighed and representative berry samples taken for skin and juice analyses. Some of the berries were crushed by hand and the juice allowed to remain in contact with the skins and lees at 15°C for 24 hours (skin contact juice), after which the juice was separated from the remainder of the berries. The juice was analysed for applicable characteristics using standard methods of the Viticulture and Oenology Department.

Canopy measurements

Canopy density measurements were taken, using the point-quadrant method and light measurement within and outside the canopy using a LI-COR 191 SA "Line Quantum Sensor" light metre. Total length per shoot (main shoot length plus lateral shoot length) of eight randomly selected shoots per site was measured after v,raison.

Soil

The soil of the Meerlus vineyard was identified as yellow brown, gravelly (80%) Oakleaf/Tukulu soils, with respectively 6% and 9% clay in the A and B horizons, underlaid at 1050 mm by heavier texture (60% clay) material. On Kersfontein a yellow brown Oakleaf soil, with respectively 16% and 34% clay in the A and B horizons, was underlaid by lighter texture (25% clay, 25-30% fine gravel) material.

Only the Ca(OH)2 application increased the pH of the 0-30 cm soil layer significantly (Table 1), while at the same time reducing the extractable H thereof (Table 3). Although Ca(OH)2 is the most motile liming matter (Kotze & Joubert, 1978), in this investigation it only increased the pH of the 0-30 cm soil layer significantly. This corresponds

Table 3: The effect of different Ca and Mg soil applications on the extractable acid, potassium saturation and phosphorus content of soil from two farms (Meerlus and Kersfontein) in the Paardeberg area, one year after application.

Main effects	Soil treatment	Soil depth (cm)	Meerlus	Kersf.	Treatment Average[1]	Meerlus	Kersf.	Treatment Average[1]	Meerlus	Kersf.	Treatment Average[1]
			H ($cmol_c\ kg^{-1}$)			K-vers.[2] (%)			P ($mg\ kg^{-1}$)		
Soil treatment			1.00	1.07	**1.03 a**	7.91	10.98	9.35	38.4	34.9	**36.6 a**
	$CaSO_4$	0-30	0.94	1.09	**1.01 a**	6.73	8.52	7.59	40.0	34.9	**37.4 a**
	$Ca(OH)_2$	0-30	0.45	0.64	**0.54 b**	6.72	9.14	8.01	35.5	37.3	**36.4 a**
	$MgSO_4$	0-30	0.97	1.11	**1.04 a**	7.45	7.91	7.69	42.2	27.2	**34.7 a**
Farm	Average [3]	0-30	**0.84 b**	**0.98 a**	0.91	6.81	9.38	8.17	**39.0 a**	**33.6 a**	36.3
Soil treatment			1.48	1.22	**1.35 a**	4.29	6.22	5.42	27.2	20.9	**24.1 a**
	$CaSO_4$	30-60	1.16	1.31	**1.24 a**	5.73	6.96	6.37	25.0	22.0	**23.5 a**
	$Ca(OH)_2$	30-60	1.28	1.31	**1.29 a**	5.00	7.75	6.38	23.0	21.6	**22.3 a**
	$MgSO_4$	30-60	1.24	1.20	**1.22 a**	4.43	6.25	5.39	23.1	18.8	**21.0 a**
Farm	Average [3]	30-60	**1.29 a**	**1.26 a**	1.28	5.03	6.67	5.85	**24.6 a**	**20.8 b**	22.7
Soil treatment			2.05	1.09	**1.57 a**	3.54	4.94	4.25	17.3	17.4	**17.4 a**
	$CaSO_4$	60-90	2.03	1.17	**1.60 a**	3.59	4.75	4.22	21.3	17.9	**19.6 a**
	$Ca(OH)_2$	60-90	1.92	1.17	**1.54 a**	3.83	4.79	4.39	18.0	18.3	**18.1 a**
	$MgSO_4$	60-90	1.86	1.10	**1.48 a**	3.43	4.24	3.73	16.6	16.3	**16.5 a**
Farm	Average [3]	60-90	**1.96 a**	**1.13 b**	1.55	3.71	4.51	4.19	**18.3 a**	**17.5 a**	17.9

[1] Treatment averages for the same measured characteristic and depth, followed by the same letters, do not differ significantly at P≤0.05.
[2] Potassium saturation is expressed as the percentage that extractable K constitutes of the T value (T = basic cations + extractable H).
[3] Farm averages for the same measured characteristic and depth, followed by the same letters, do not differ significantly at P≤0.05.

with the findings of Kotze & Deist (1975), indicating that the effect of Ca(OH)2 on pH is limited mainly to the depth of application.

Calcium sulphate significantly reduced the pH(H2O) of the 0-30 cm soil layer. This can possibly be attributed to a higher salt concentration in the soil solution that was thus obtained, as indicated by the significantly lower Rs. It is known that an added salt is able to displace nitrogen ions from the soil colloid in order to reduce the soil pH (Mengel & Kirkby, 1987a).

According to Table 2 the significant increase in extractable Ca effected by CaSO4 and Ca(OH)2, was also limited to the 0-30 cm soil layer. On the other hand MgSO4 resulted in a significant increase in extractable Mg even in the 60-90 cm soil layer on Kersfontein. Possible explanations for the differences in depth between the Mg and Ca movements, are the higher solubility of MgSO4 compared to CaSO4 and Ca(OH)2 (Hodgman, 1950) and the weaker adsorption of Mg to the soil colloid, compared to Ca (Mengel & Kirkby, 1987a). Both these factors will play a role in making Mg more motile in the soil than Ca. It is not known, however, why MgSO4 significantly increased the extractable Mg to a depth of 60-90 cm on Kersfontein only, despite a higher clay content in the soil than Meerlus.

Only the MgSO4 soil application, and only on Kersfontein, was able to reduce the extractable K of the 0-30 cm soil layer (Table 2). This reduction in K possibly occurred because the Mg displaced the K on the soil colloid and by so doing increased the concentration of K in the soil solution and the subsequent leaching thereof, resulting in a significant reduction in the extractable K of the 0-30 cm soil layer. A lower soil pH will increase the concentration of K in the soil solution (Thomas & Hipp, 1968) and such an increase could possibly promote the leaching of this cation (Mengel & Kirkby, 1987a). It is possible that the significantly lower soil pH of the 0-30 cm soil layer on Kersfontein, compared to Meerlus (Table 2), contributed to the MgSO4 having significantly reduced the extractable K of the 0-30 cm soil layer on Kersfontein only (Table 2). It seems therefore that the higher solubility of MgSO4 compared to the other fertilisers, caused Mg to be a more effective exchanger of K than Ca.

Both Ca(OH)2 and CaSO4 were ineffective as far as the reduction of the K content of the soil layers is concerned (Table 2), but appear to have reduced, just like the MgSO4, the percentage K saturation in the top soil (Table 3) due to the resulting high percentage Ca and Mg saturation (data not shown). The increase in soil pH, together with the low solubility of Ca(OH)2, limited the effectiveness of this lime to displace K from the soil colloid. This limitation possibly contributed to the fact that Ca(OH)2 did not significantly reduce the extractable K of the soil layers (Table 2).

The K content of the 0-30 cm soil layer on both Kersfontein and Meerlus was still much higher than the usual

Table 4: The effect of different Ca and Mg soil applications on the canopy density and shoot length of grapevines on two farms (Meerlus and Kersfontein) in the Paardeberg area; 1999/00 growing season.

Main effects		Meerlus	Kersf.	Treatment[1] Average	Meerlus	Kersf.	Treatment[1] Average
		Full sun [2] (%)			Total lenght per shoot (cm)		
Soil treatment	Control	11.2	22.3	**16.8 ab**	102.8	129.5	**116.1 a**
	$CaSO_4$	12.8	24.9	**18.8 a**	100.1	112.9	**106.5 a**
	$Ca(OH)_2$	12.3	22.3	**17.3 ab**	97.5	130.0	**113.8 a**
	$MgSO_4$	10.0	19.0	**14.5 b**	104.3	136.5	**120.4 a**
Farm	Average [5]	**11.6 b**	**22.1 a**	16.9	101.2 [4]	127.2	114.4
		Shade bunches (%)			LLC		
Fertilisation	Control	55	43	**48 a**	2.1	1.9	**2.0 a**
	$CaSO_4$	46	41	**43 a**	2.2	1.9	**2.0 a**
	$Ca(OH)_2$	55	41	**47 a**	2.3	2.1	**2.3 a**
	$MgSO_4$	53	46	**49 a**	2.3	2.2	**2.2 a**
Farm	Average [5]	**52 a**	**42 b**	47	**2.2 a**	**2.0 a**	2.1

[1] Treatment averages for the same measured characteristic and depth, followed by the same letters, do not differ significantly at P≤0.05.
[2] Full sun = 1252 µmol foton m-2 s-1
[3] Averages for the same main effect, followed by the same letters, do not differ significantly at P≤0.05.
[4] As a result of the significant interaction between main effects, treatment and farm averages cannot be compared with each other statistically.
[5] Farm averages for the same measured characteristic and depth, followed by the same letters, do not differ significantly at P≤0.05.
LLC = Leaf layer count

average of 4% K saturation (Table 3), generally considered to be optimal for viticulture. According to Conradie (1994) a K content of 70-80 mg kg-1 (0.18-0.21 cmolc kg-1) is optimal for viticulture on soils with a history of lime application. According to Table 2 the K content of the 0-30 cm and 30-60 cm soil layers on both Kersfontein and Meerlus exceeds this average.

Magnesium sulphate significantly reduced the extractable Ca and CaSO4 the extractable Mg of the 0-30 cm soil layer (Table 2). The increase in soil pH through Ca(OH)2 (Table 1) appears to have limited the leaching of Mg and so too the extractable Mg (Table 2).

The chemical soil treatments had no significant influence on the P content of the soils.

Plant

Despite obviously longer shoots the canopy on Kersfontein was less dense than on Meerlus, as can be seen from the percentage full sun, the percentage shade bunches and LLC data (Table 4). Although there are indications that Mg-sulphate applications resulted in a lower percentage of full sun in the foliage, this was not reflected by total shoot length, shade bunches or LLC.

Table 5 indicates that the chemical soil treatments had no effect on the measured bunch characteristics. The production per vine of the Kersfontein Cabernet Sauvignon was significantly lower, however, than that of the Meerlus Cabernet franc and may be linked to lower bunch mass, with larger berries.

According to Table 6 it seems that the sugar contents on Kersfontein were generally higher than on Meerlus. Ca-hydroxide and Mg-sulphate soil applications significantly increased the sugar content on Kersfontein. In contrast Ca and Mg soil applications on Meerlus did not have any significant effect on the sugar content of juice compared to the control. The latter result confirms that of Ruhl et al. (1992), Daverede & Garcia (2000) and Gallego (1999), who did not find any effect on the sugar content of juice following MgSO4, CaCl2 and CaCO3 applications.

Table 1 indicates that the Control topsoil pH on Kersfontein (pH(KCl) of 4.7) was significantly lower than on Meerlus (pH(KCl) of 5.5). Trenching of the soil on Kersfontein was not as deep and consequently the root system of these vines was not as deep as on Meerlus. From the above it seems, therefore, that the physical and chemical soil characteristics on Kersfontein were less optimal for viticulture than on Meerlus. One might therefore assume that if the application of Ca or Mg to the soil had a positive effect on the sugar content of juice, it would be more prominent in the case of Kersfontein. However, the specific mechanism involved in the increase of the sugar content of juice by Ca(OH)2 and MgSO4 on Kersfontein (Table 6) is not known.

Only on Meerlus diid the application of Ca and Mg significantly reduce the pH of the juice, while MgSO4 resulted in a significant increase on Kersfontein (Table 6). According to Boulton (1980a) the pHs of juice and wine are determined mainly by the tartaric/malic acid (TA/MA) ratio, titratable acids (TiA), Na and K content thereof. Seeing that Ca and Mg fertilisation on Meerlus

Table 5: The effect of different Ca and Mg soil applications on bunch characteristics of grapevines on two farms (Meerlus and Kersfontein) in the Paardeberg area; 1998/99 growing season.

Main effects	Beh.	Meerlus	Kersf.	Treatment[1] Average	Meerlus	Kersf.	Treatment[1] Average
		Crop mass per vine (kg)			Bunch mass (g)		
Fertilisation	Control	4.77	2.75	**3.76 a**	119.4	91.9	**105.6 a**
	$CaSO_4$	4.65	2.76	**3.71 a**	118.7	88.9	**103.8 a**
	$Ca(OH)_2$	4.56	2.24	**3.40 a**	118.9	87.5	**104.6 a**
	$MgSO_4$	4.73	2.17	**3.45 a**	122.3	92.4	**108.7 a**
Farm	Average[2]	**4.68 a**	**2.48 b**	3.58	**119.8 a**	**90.2 b**	105.0
		Number of bunches per vine			Berry mass[3] (g)		
Fertilisation	Control	41	30	**35 a**	**1.23 a**	**1.51 a**	1.37
	$CaSO_4$	40	32	**36 a**	**1.24 a**	**1.59 a**	1.42
	$Ca(OH)_2$	39	26	**33 a**	**1.22 a**	**1.59 a**	1.41
	$MgSO_4$	39	24	**32 a**	**1.18 a**	**1.57 a**	1.38
Farm	Average[2]	**40 a**	**26 b**	33	1.22 [4]	1.56	1.39

[1] Treatment averages for the same measured characteristic and depth, followed by the same letters, do not differ significantly at P≤0.05.
[2] Farm averages for the same measured characteristic and depth, followed by the same letters, do not differ significantly at P≤0.05.
[3] Averages for the same farm and main effect, followed by the same letters, do not differ significantly at P≤0.05.
[4] As a result of the non-homogeneity of variation between farms, farm and treatment averages could not be compared with each other statistically.

did not indicate any significant influence on the Na and K content of juice (data not shown), one may assume that Ca and Mg fertilisation reduced the juice pH by increasing the TiA (this data is not available for Meerlus) and/or TA:MA (this data is not available either) ratio of the juice.

Daverede & Garcia (2000) also obtained a significant reduction in juice pH in vines that were hydroponically grown, following the application of an excess of Ca as CaCl2 and ascribed it to a K/Ca antagonism, which significantly reduced the K content and therefore also the pH of juice.

No obvious K/Ca antagonism occurred following the CaSO4 treatment on Meerlus, as there was no significant reduction in the K content of either the petioles or the juice (data not shown). This could possibly be because the applied Ca concentration in the soil was too low and because Ca was neither properly distributed nor sufficiently deep (Table 2).

The concentration of K in the soil solution may also have an influence, however, on a K/Ca antagonism. According to Maathuis & Sanders (1996) active uptake of K in higher plants has a greater selectivity for K than in the case of passive uptake. One might therefore conclude that the possibility of a K/Ca antagonism would increase with an increase in passive K uptake. Epstein (1973) also proved that a high external Ca concentration was able to limit the passive uptake of K. According to Maathuis & Sanders (1996) passive uptake will be dominant at high external K concentrations in the millimolar area, while active uptake will be dominant at lower concentrations in the micromolar area. As a result of the exhaustion zone of K that forms around the surface of roots, K is absorbed into the micromolar concentration area in

Table 6: The effect of different Ca and Mg soil applications on the pH, acid and sugar content of juice1 deriving from grapevines on two farms (Meerlus and Kersfontein) in the Paardeberg area; 1998/99 growing season.

Main effects	Soil treatment	Meerlus	Kersf.	Treatment Average	Meerlus	Kersf.	Treatment Average	Meerlus	Kersf.	Treatment Average
		pH[3]								
Soil treatment	Control	**3.95 a**	**3.35 b**	3.65	-	**7.30 a**	-	**21.50 ab**	**22.20 c**	21.85
	$CaSO_4$	**3.78 b**	**3.43 b**	3.61	-	**8.14 a**	-	**21.92 a**	**22.20 c**	22.06
	$Ca(OH)_2$	**3.70 b**	**3.55 ab**	3.63	-	**6.83 a**	-	**21.60 ab**	**23.08 b**	22.34
	$MgSO_4$	**3.67 b**	**3.75 a**	3.71	-	**6.49 a**	-	**21.35 b**	**24.10 a**	22.73
Farm[2]	Average	3.77	3.52	3.65	-	7.19	-	21.59	22.90	22.24

[1] Skin contact juice was used for analyses. 2 As a result of the non-homogeneity of variation between farms, farm and treatment averages could not be compared with each other statistically. 3 Averages for the same farm, measured characteristics and main effect, followed by the same letters, do not differ significantly at P≤0.10. 4 The TiA of Meerlus is not given due to faulty analyses.

most soils. If one therefore assumes that the active uptake of K also played an important role on Meerlus, this may have inhibited the possibiliy of a K/Ca antagonism. The occurrence of a K/Ca antagonism as described by Daverede & Garcia (2000) can also be explained, since the importance of passive K uptake will possibly increase under hydroponic conditions, thereby increasing the possibility of a K/Ca antagonism.

It seems therefore that the CaSO4 soil applications on Meerlus reduced the juice pH by promoting the synthesis and/or retention of certain acids. The reason for this is not known, however, as it contradicts research by Daverede & Garcia (2000) who found that CaCl2 fertilisation significantly reduced the malic acid content of juice, while it had no significant influence on TA and TiA content of juice.

Gallego (1999) experienced a significant increase in TiA and reduction in K content of juice in reaction to CaCO3 fertilisation on four different soil types. Although it was not significant, a reduction in juice pH was also found on all four different soil types involved. The reduction in juice pH is also explained by a K/Ca antagonism.

As in the case of the CaSO4 treatment on Meerlus, it is unlikely that the significant reduction in juice pH on Meerlus by the Ca(OH)2 treatment may be ascribed to a K/Ca antagonism, in that Ca(OH)2 fertilisation did not result in a significant reduction in the K status of the vine and juice K on Meerlus (data not shown). It is also unlikely that the increase in soil pH would have reduced the K concentration of the soil solution to such an extent that it limited the K uptake, as the uptake of K is not dependent on the K concentration in the soil, provided a shortage does not occur (Boulton, 1980b) or passive K uptake does not play an important role (Maathuis & Sanders, 1996). As a result of the high K concentration and percentage saturation of the topsoil, especially on Meerlus (Table 2; 3), and the fact that the increase in soil pH is limited to a 0-30 cm soil layer only (Table 1), it is unlikely that K uptake would be hampered significantly.

As in the case of CaSO4, it seems that Ca(OH)2 reduced the juice pH significantly by promoting the synthesis and/or retention of certain acids on Meerlus.

Soil applications of MgSO4 on Meerlus also reduced the juice pH significantly (Table 6). This corresponds with results obtained by Ruhl et al. (1992), who also found a significant reduction in wine pH of Chardonnay in reaction to MgSO4 fertilisation. According to the authors the reduction was to be expected due to the occurrence of a possible K/Mg antagonism in vines, as described by Loué, Gaynard & Morard (1987), and reported in Ruhl et al. (1992). However, the expected antagonism did not occur in the trial of Ruhl et al. (1992), as there was no significant difference in the K content of wines. Mengel & Kirkby (1987b) also discussed the possibility that an increase in Mg fertilisation might reduce the K content of plants by means of a K/Mg antagonism. In the MgSO4 treatment on Meerlus there probably did not occur any K/Mg antagonism, seeing that there wasn't any significant reduction in the K content of juice (data not shown). According to Conradie & Saayman (1989a) no Mg induced K deficit (K/Mg antagonism) has been identified in any SA vineyard up to now. The opposite trend is, however, a common occurrence in leaf analyses (Conradie, 1994; Garcia et al. 1999).

With regard to MgSO4 soil applications, these also seem to have promoted the synthesis and/or retention of certain acids on Meerlus in order to bring about a significant reduction in juice pH.

At this stage one can only speculate as to why Ca and Mg fertilisation reduced the juice pH on Meerlus only, while increasing it significantly on Kersfontein, since there are too many differences between Meerlus and Kersfontein. Research by Ruhl et al. (1992) indicates that the influence of fertilisation on wine pH may differ from one cultivar to the next, as MgSO4 fertilisation in a trial only reduced the wine pH of one out of three cultivars significantly. Conradie (1983) also proved that liming is able to influence the K content of shoots differently, depending on the rootstock cultivar and the increase in soil pH that is brought about. The relationship between the K content and pH of juice and wine (Boulton, 1980a) allows one to conclude that the possible effect of liming on juice and wine pH will differ, depending on the increase in soil pH and rootstock cultivar.

According to Jackson & Lombard (1993) the pH and sugar content of juice usually increase along parallel lines during ripening. The significantly higher sugar content of juice from the Ca(OH)2 and especially the MgSO4 treatments on Kersfontein (Table 6) suggests earlier ripening and may serve as an explanation for the significant increase in pH and inclination to lower acids in the case of the MgSO4 treatment.

Conclusions

Calcium hydroxide and especially MgSO4 applications may be used successfully, given the conditions of the field trial, to increase the sugar content of the juice of Cabernet Sauvignon/101-14 Mgt significantly, probably due to earlier ripening, as reflected by higher pHs. Magnesium sulphate also appears to be the most effective soil application to reduce absolute K contents of the soil, but the effectiveness thereof is clearly dependent on the soil and there is no obvious explanation for this phenomenon. Under the conditions of the field trial, calcium and Mg fertilisation could also be used successfully to reduce the juice pH of Cabernet franc/99R significantly. The reason for this reduction is not known either. Further research is required to identify the specific mechanisms involved in these reactions.

The K saturation of the soils in question was so high that bigger concentrations of Ca and/or Mg ions will probably be necessary in the soil solution to induce a K/Ca or K/Mg antagonism successfully in order to achieve lower K levels in the juice and wine. Although magnesium sulphate appeared to have been the most promising soil application, excessively high applications of Mg salts may be harmful to the soil structure. Further research into this matter is required,

also regarding the possibility of bunch directed Ca or Mg spraying at different phenological stages.

References

BOULTON, R., 1980a. The general relationship between potassium, sodium and pH in grape juice and wine. Am. J. Enol. Vitic. 31, 182 - 186.

BOULTON, R., 1980b. A hypothesis for the presence, activity, and role of potassium/hydrogen, adenosine triphosphatases in grapevines. Am. J. Enol. Vitic. 31, 283 - 287.

CHAMPAGNOL, F., 1994. Facteurs agronomiques de l'acidité des moûts et des vins. Progrès Agric. Vitic. 111, 469 - 481.

CONRADIE, W. J., 1983. Liming and choice of rootstocks as cultural techniques for vines in acid soils. S. Afr. J. Enol. Vitic. 4, 39 - 44.

CONRADIE, W.J., 1994. Wingerdbemesting. Handelinge van die Werksessie oor Wingerdbemesting. ARC-Nietvoorbij Institute for Viticulture and Oenology, Private Bag X5026, Stellenbosch, 7599.

CONRADIE, W. J. & SAAYMAN, D., 1989a. Effects of long-term nitrogen, phosphorus and potassium fertilization on Chenin blanc vines. I. Nutrient demand and vine performance. Am. J. Enol. Vitic. 40, 85 - 90.

CONRADIE, W. J. & SAAYMAN, D., 1989b. Effects of long-term nitrogen, phosphorus and potassium fertilization on Chenin blanc vines. II. Leaf analyses and grape composition. Am. J. Enol. Vitic. 40, 91 - 97.

DAVEREDE, C. & GARCIA, M., 2000. Effect of various K-Ca ratios on the lack of acidity of musts and wines of Vitis vinifera L. cv. Négrette grafted on 101.14 M.G. and grown hydroponically. Accepted in: Am. J. Enol. Vitic. 50.

EPSTEIN, E., 1973. Mechanisms of ion transport through plant cell membranes. Int. Rev. Cytol. 34, 123 - 168.

ETOURNEAUD, F., 1996. The Role of Potassium as One Parameter Monitoring the Acidity of Wines: Consequences on Potash Fertilisation of Vine. SCPA Agronomic Research Center.

GALLEGO, P., 1999. Influence des terroirs de l'appellation d'origine controlee "Côtes du Frontonnais" sur la nutrition cationique et le manque d'acidite des mouts et des vins de Negrette (Vitis vinifera L.) greffee sur 3309 C. Doctoral thesis. L'Institut National Polytechnique de Toulouse.

GARCIA, M., DAVEREDE, C., GALLEGO, P. & TOUMI, M., 1999. Effects of various potassium-calcium ratios on cation nutrition of grapes grown hydroponically. J. Plant Nutri. 22, 417 - 425.

HODGMAN, C.D., 1950. Handbook of Chemistry and Physics: A Ready-reference Book of Chemical and Physical Data, 32nd ed. Chemical rubber publishing co., Cleveland Ohio.

JACKSON, D.I. & LOMBARD, P.B., 1993. Environmental and management practices affecting grape composition and wine quality - A review. Am. J. Enol. Vitic. 44, 409 - 430.

KOTZE, W.A.G. & DEIST, J., 1975. Amelioration of subsurface acidity by leaching of surface applied amendments: A laboratory study. Agrochemophysica 7, 39 - 45.

KOTZE, W.A.G. & JOUBERT, M.E.,1978. The mobility of liming materials in soils. Decid. Fruit Grow. 28, 440 - 444.

MAATHUIS, F.J.M. & SANDERS, D., 1996. Mechanisms of potassium absorption by higher plant roots. Physiol. Plant. 96, 158 - 168.

MENGEL, K. & KIRKBY, E.A., 1987a. The Soil as a Plant Nutrient Medium. In: Principles of Plant Nutrition, 4th ed. International Potash Institute, Bern.

MENGEL, K. & KIRKBY, E.A., 1987b. Nutrient Uptake and Assimilation. In: Principles of Plant Nutrition, 4th ed. International Potash Institute, Bern.

RUHL, E.H., FUDA, A.P. & TREEBY, M.T., 1992. Effect of potassium, magnesium and nitrogen supply on grape juice composition of Riesling, Chardonnay and Cabernet Sauvignon wines. Aust. J. Exp. Agric. 32, 645 - 649.

SIEGFRIED, H.P., 1993. The Malmesbury Batholith and its relationship to granitic plutons in the Swartland tectonic domain. Ph.D. thesis. Univ. of Stellenbosch, Private Bag X1, Matieland, 7602.

SOMERS, T. C., 1975. In search of quality for red wines. Food Tech. Aust. 27, 49 - 56.

THOMAS, G.W. & HIPP, B.W., 1968. Soil Factors Affecting Potassium Availability. In: V.J. Kilmer, S.E. Younts & N.C. Brady (Eds). The Role of Potassium in Agriculture. Am. Soc. Agron. Madison, Wis.

WOOLDRIDGE, J., 1985. The potassium supplying power of orchard soils of the Western Cape. Potassium Symp. Potassium Symp. Organising Committee, Pretoria, pp. 55 - 61.

Bud break patterns in the Olifants River Valley during the 2004 and 2005 seasons Part (I)

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Introduction

A vine is dormant during the period from leaf drop to bud break, in other words it is resting. The flow of juice in the phloem is prevented, because the sieve plates are blocked with callose and juice flow does not take place in the xyleme, because the roots are inactive (Burger & Deist, 1981). Dormancy is characterised by the temporary arrest of "visible growth" of any plant structure that has a meristem (Lang et al., 1987) and is therefore a safety mechanism in the endogenous rhythm of the vine to escape from unfavourable conditions (literature in Goussard, 2002). The induction and arrest of dormancy are regulated by various factors within as well as outside the plant.

According to Lang et al. (1987) dormancy may be divided into:

a. Paradormancy when the bud is kept dormant by physiological factors outside the dormant structure, but within the plant itself, for example apical dominance and photoperiodic reactions. The biochemical signal therefore originates in another structure besides the bud.
b. Endodormancy which is controlled by physiological factors within ("endo") the dormant structure, for example the specific reaction to an environmental or endogenous signal.
c. Ecodormancy when the bud is kept dormant by unfavourable environmental conditions, for example low temperatures or water and nutrient deficiencies. This may be considered to be a temporary arrest of growth until all the basic requirements for growth such as water, temperature, nutrients as well as oxygen and carbon dioxide levels are met.

According to Coombe (1995) "bud break" may be described as "E-L stage 4". This is the "green point bud" stage when the first leaf tissue becomes visible. Bud break is said to have occurred when 50% buds on the bearer shoots have reached the "green point bud" stage (literature in Lombard, 2003a).

Poor and uneven/delayed bud break may result in uneven ripening, as well as reduced yield with the accompanying financial and logistic implications. Research and knowledge of bud break patterns and possible reasons for the occurrence of delayed bud break are therefore of cardinal importance when an attempt is made to manage vineyards in such a way that financial losses are limited to the minimum.

This is the first of two discussions which describe bud break patterns that have been observed in the Olifants River during the 2004 and 2005 seasons and offer possible explanations for certain phenomena. Prevailing climatic conditions are discussed as well as water shortages, which are concomitant with the increased occurrence of salts.

Prevailing climatic conditions

The 2004 season was characterised by "untimely/post-harvest bud break" (Figure 1 and Figure 2) of the apical buds ("green flags") and in certain instances even the budding of base buds on the bearer shoots. On the other hand early bud break, in Colombard especially, and uneven/delayed bud break, in Chardonnay (Figure 3) and Shiraz (Figure 4) especially, occurred during the 2005 season with uneven ripening (Figure 5 and Figure 6) that complicated management for a specific wine goal in 2006.

Although there is no significant difference in the average monthly temperatures over the past four seasons (Table 1), it appears that May 2004 and June 2004 (Vredendal area) were slightly warmer than the other three seasons. This could possibly explain why vine buds did not go into dormancy and renewed bud break occurring in June and July 2004. According to literature in Goussard (2002) green apical parts of the vine can remain alive during warm winters and it is therefore possible that apical buds will not go into dormancy like the base buds. Bud break can therefore start during warm autumn and winter conditions.

Similarly, although not significantly so, July 2005 appears to have been warmer than the previous three seasons. From Table 2 it is clear, however, that in July 2005 the cumulative number of degree hours above 22°C, was significantly higher than the previous four seasons (5% level of significance), while 2002 had a particularly cold month of July.

The temperature loggers are situated on soils outside the irrigation scheme on the left and right banks of the Olifants River, between Lutzville and Vre-

Table 1: The average monthly temperature (°C) (Vredendal area) for May to September over the last four seasons (2002-2005) as well as the long term average.

	2002	2003	2004	2005	LT*
May	15.05	17.29	17.45	15.77	17.53
June	11.90	14.05	14.24	12.97	15.27
July	11.97	14.34	13.74	15.66	14.56
August	13.50	12.33	14.03	12.48	15.02
September	17.16	14.92	16.48	15.35	16.56

LT* – The long term average (30 years to February 2000) is for the weather station at Lutzville experiment farm (Infruitec, Stellenbosch data) while the figures for the four years are the averages collected by three temperature loggers distributed over the Vredendal area (J. Joubert, 2008).

FIG 1: Budding of apical buds in Shiraz (Jul. 2004).

FIG 2: Pruning of Shiraz in an attempt to prevent depletion of reserves (Aug. 2004).

FIG 3: Uneven budding in Chardonnay (Sept. 2005).

FIG 4: Uneven budding in Shiraz (Sept. 2005).

FIG 5: Uneven ripening in Shiraz (Jan. 2006).

FIG 6: Pinotage bunches picked in the same vineyard block (Jan. 2006).

FIG 7: Budding of apical buds in Chardonnay (July 2004).

FIG 8: Poor budding in Chardonnay possibly due to exhaustion of reserves and brackish conditons (Oct. 2004).

dendal ("Vredendal" and "Holrivier"), and on the right bank between Vredendal and Klawer ("Karoovlakte").

The enforced rest period from about mid June to August, which occurs as a result of winter cold (Pienaar, 1988), was possibly interrupted by high July temperatures in 2005 and bud break was imminent. Cold followed in August, growth was arrested and uneven/delayed bud break possibly ensued.

From the Pienaar model it appears that average weekly temperatures of 15°C and lower with minimum daily temperatures of 9.9°C and lower, over periods of three days and longer during the latter part of May and early June, may have an effect on dormancy breaking in vine buds (Pienaar, 1988). The minimum towards the end of May in particular is important for dormancy breaking. According to Archer and Goussard (1988) the most important causes of delayed bud break during the 1986/87 and 1987/88 growing seasons may be attributed to high minimum temperatures (possibly temperatures above 10°C) in the early part of winter, May in particular. Pienaar (1988) conducted his study at Nietvoorbij, Stellenbosch and it does not necessarily apply to all the other viticultural regions. Factors such as daylight hours, sunlight intensity, rainfall and soil temperatures that influence bud break, differ from region to region.

Individually all three stations comply with the requirements demanded by the Pienaar model (data not shown, J. Joubert, 2006), but from Table 3 it is clear that "Holrivier" experienced average minimum temperatures above 10 degrees Celsius during the last two weeks of May 2003 and May 2005. This provides a further possible explanation for uneven bud break tendencies in certain vineyard blocks during the 2005 season. According to Hackett and Holzapfel (2002) bud break in vines the next spring may be "patchy" with distal buds (further away from the base of the shoot), which exerts apical dominance on the bud break of more proximal buds, if autumn and winter temperatures do not comply with the required cold unit requirements. This has an influence on canopy formation and may result in a drastic decline in yield if no corrective measures are taken.

Water shortages with increased concentration of salts

In vines that were subjected to severe moisture stress during the growing season, bud break tends to occur after the first autumn rain, which causes all

Table 2: The cumulative number of degree hours above 22°C for July collected by three temperature loggers in the course of four seasons (2002-2005).

July	Holrivier	Karoovlakte	Vredendal
2002	82.8	96.5	90.8
2003	372.7	416.3	373.4
2004	326	307.3	334.1
2005	501.9	588.2	585.5
Average 2002-2005	320.85	352.08	345.95

Table 3: The average minimum temperature (°C) for the last two weeks in May (three temperature loggers) over four seasons (2002-2005).

Ward	Co-ordinates	2002	2003	2004	2005
Holrivier	31°35'S; 18°23'O	9.96	11.06	9.58	10.23
Vredendal	31°40'S; 18°28'O	9.28	8.86	8.75	6.22
Karoovlakte	31°42'S; 18°33'O	8.78	7.86	9.52	6.58

the reserve nutrients to be used, thereby making the vine less equipped for the subsequent season (literature in Burger & Deist, 1981). During the 2003/2004 season producers saw a reduction in their irrigation allocation, with the result that vines had to make do with less water and in some instances vines were subjected to severe water stress. In many instances early cultivars in particular did not receive post-harvest irrigation, since the water was reserved for later ripening cultivars. In some instances re-growth occurred with post-harvest irrigation (competition from bunches was removed) under favourable temperature conditions (month of May). According to Winkler et al. (1974) the vine never stops growing entirely and the shoots may lengthen at any time if there is sufficient heat, sufficient moisture in the soil, for example after irrigation or rain, with sufficient levels of nitrogen. As can be seen from Figure 7 and Figure 8, untimely budding of apical buds indicate the sandy and brackish parts ("bad patches"), and therefore the parts that were most subjected to moisture stress.

Insufficient soil water content (water stress) in the period just prior to bud break can have a drastic impact on bud break. Lipman (date unknown) emphasises that sufficient soil moisture should be available towards the end of winter to assist the rising soil temperature. According to Hackett & Holzapfel (2002) the biggest impact of a dry winter, with the concomitant dry soils, is on root physiology, as it may result in the increased loss of fine roots. A damaged root system may result in impaired uptake of water and nutrients early in spring and may also influence the formation of growth regulators. Abscissin acid (ABA), considered the main stressor, is formed in the leaves via the phytochrome system as a result of shorter days and translocated to shoots where it inhibits growth and brings about dormancy. ABA levels increase during dormancy and reach a maximum during endodormancy when water levels in the bud are low (literature in Lombard, 2003a). The influence of ABA is arrested by cytoquinin, which is produced in the root ends (literature in Goussard, 2002).

Conclusion

The average monthly temperature in itself does not explain the untimely/post-harvest bud break of vines during autumn and winter 2004, and this should rather be attributed to a combination of factors.

High July temperatures followed by cold periods appear to be part of the explanation for uneven/delayed bud break in September and October 2005, as well as high minimum temperatures (>10°C) in certain parts during the last two weeks of May 2005. Furthermore, the considerably higher cumulative number of degree hours above 22°C during July 2005, especially compared to the previous three years (Table 2), could also offer an explanation for the occurrence of delayed/uneven bud break in 2005.

Threshold values below which temperatures must drop for dormancy breaking are determined genetically and are cultivar bound (Pienaar, 1988). The average minimum temperature of "Holrivier" for the last two weeks in May is higher than that of the other two stations, once again emphasising the importance of selecting the right terrain for the establishment of vineyards.

Comprehensive dormancy breaking models should be investigated in the respective viticultural regions in an attempt to predict budding patterns in order to facilitate the management of vineyards.

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References

ARCHER, E. & GOUSSARD, P.G. 1988. Strategie vir bekamping van vertraagde bot by wingerd. Wynboer Tegnies. 28, 4 - 6.

BURGER, J. & DEIST, J. 1981. Wingerdbou in Suid-Afrika. Second edition. CTP Printers, Cape Town. bl. 219 - 220, 242, 530.

COOMBE, B.G. 1995. Adoption of a system for identifying grapevine growth stages. Australian Journal Grape & Wine Research. 1, 100 - 110.

GOUSSARD, P.G. 2002. Dormansie. Department of Viticulture and Oenology, Stellenbosch University. Bl. 59, 73, 88.

HACKETT, S. & HOLZAPFEL, B. 2002. Factors underlying restricted spring growth in vineyards. Australian Viticulture. 6 (5), 76 - 81.

LANG, G.A., EARLY, J.D, MARTIN, G.C. & DARNELL, R.L. 1987. Endo-, para-, and ecodormancy: Physiological terminology and classification for dormancy research. HortScience. 22 (3), 371-377.

LIPMAN, A. Date unknown. PIRSA Agriculture - Irrigation of Viticulture - Check your vineyard soil moisture. *Webblad*. 21 Maart 2006.

LOMBARD, J. 2003a. Rus en rusbreekpraktyke by tafeldruiwe. *Web page*. 16 Augustus 2004.

PIENAAR, J. 1988. Voorkoms van vertraagde bot in 1987. Wynboer Tegnies. 29, 4 - 6.

WINKLER, A.J. et al. 1974. General Viticulture. Revised and enlarged edition. University of California Press. Berkely, Los Angeles, London. Bl. 105.

Bud break patterns in the Olifants River Valley during the 2004 and 2005 seasons Part (II)

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Introduction

Dormancy and the breaking/induction thereof is a complex process influenced by various factors. In a previous article prevalent climatic conditions and water shortages with an increased occurrence of salts was discussed as possible causes for budding patterns observed in the Olifants River Valley during the 2004 and 2005 seasons.

In this article the focus is on mechanical damage to vineyards and its influence on budding, as well as strategies to limit the occurrence of uneven/delayed budding.

Mechanical damage

It is likely that as much as 80% of the total crop in the Olifants River is harvested mechanically (J. Joubert, personal communication, 2006). "Green flags" were noted in certain instances during the 2004 season, where shoots were damaged and/or broken as a result of mechanical harvesting – damaged or broken shoots appear black in the middle (J. Joubert, personal communication, 2004) (Figures 1 and 2).

According to literature in Goussard (2002), the budding of long dormant buds may be the result of traumatisation, for example wounds caused by sawing off arms and straight trunks, organs being blown off and the damage of organs by implements. A possible explanation is the removal of organs that function as inhibitors to budding. Although wound hormones might play a role, and so too loss of moisture, definite physiological explanations are absent. Figures 3 and 4 show budding as a result of damage caused by mechanical harvesting.

According to Hackett and Holzapfel (2002) mechanised pruning, tipping and harvesting actions may cause damage to current growth, renewal growth and trunks. Buds are isolated as a result of vascular damage thereby impacting on spring budding, while bruised trunks lead to wound reactions that include the budding of water shoots.

The damage to leaves as a result of mechanical harvesting, be it because of wounds to arms or because of "burn damage" by juice (grape acids), may exert a significant influence on the accumulation and state of reserves in the vine and consequently budding the following spring.

FIG 1: A vine arm is damaged by mechanical harvesting (Jan. 2006).

FIG 2: Mechanical damage to a Chenin blanc vine (Jan. 2006).

Preventative strategies

Reserve levels play an important role in budding. If shoot growth continues too late in autumn, the result may be a shortage of carbohydrate reserves (Burger & Deist, 1981). The efficiency of leaves in virus infected vines, red cultivars in particular, is impaired due to the loss of chlorophyll and the blockage of vascular bundles, thus impacting negatively on the accumulation of reserves. According to Smart (2001) unbalanced vines with a shortage of reserves, for example when too many buds are left by winter pruning, may result in delayed budding and limit shoot growth in the period before flowering.

Mechanical damage may further reduce reserve levels through the stimulation of untimely budding, thereby causing the exhaustion of reserves locally. To reduce the occurrence of mechanical damage to vines, the harvesting process must be monitored carefully. The beaters form the nucleus of the harvesting chamber. Distortion of the beaters may be caused by faulty tension, resulting in abnormal patterns of movement and damage to shoots and even trellis poles (author unknown, 2004). Ground speed and beater speed (intensity) must also be taken into account to limit damage to the vine to the minimum.

Vineyard characteristics that facilitate mechanical harvesting are, inter alia, evenness throughout the entire block, with all vines having upright trunks and cordons that are firmly attached to the cordon wire. A properly developed canopy will soften the impact of mechanical harvesting (Ludvigsen, 2004). Poor vine formation practices and insufficient foliage may therefore be a contributing factor to mechanical damage to vines.

Taking into account the temperature data of a particular season, clean pruning should take place as late as practically possible. Chemical dormancy breakers may be applied in an attempt to obtain more even budding. Hydrogen cyanamide (H_2CN_2) (for example Dormex®) is considered the main dormancy breaker for grapes (literature in Or *et al.*, 1999). These products influence the metabolism of the vine via the respiration system. Time of application for more even budding ranges from two to four weeks before normal budding (Archer *et al.*, 1988; Lombard, 2003b and Wiese, 1988), and preferably within 48 hours of clean pruning taking place (J. Joubert, personal communication, 2006). The timing as well as concentration of dormancy breaker application is very important; if the application is too early, it may have no or a negative effect on the evenness of budding, while application that is too late or too concentrated may cause bud damage, which may influence the production of a vineyard (Or *et al.*, 1999).

Blocks where cold accumulation does not readily take place, problem blocks, for example young vines that were fully developed on the cordon in the first year, blocks where the vine frame must be improved (Wiese, 1988) and cultivars such as Chardonnay with a high cold unit requirement, should receive dormancy breakers. No chemical product can serve as a substitute for cold demand, however, and some may even be phased out in future.

If premature/post-harvest budding occurs, young shoots may be removed, but bear in mind that such an action may encourage the budding of those buds that are situated in a lower position. In a certain sense premature budding (most apical bud/s on shoots) may be desirable, in view of the fact that it sustains dormancy in basal eyes. In the case of active budding and shoot growth of apical buds and especially in the presence of bunches, it should preferably be removed to minimise the exhaustion of reserves (P.G. Goussard, personal communication, 2004). If delayed budding occurs with apical domination of buds situated in a lower position, pruning may take place late in the season in an attempt to induce budding (Hackett and Holzapfel, 2002).

FIG 3: The budding of a long dormant bud after the trunk was damaged by mechanical harvesting (Apr. 2006)

FIG 4: Budding of a shoot after damage by a mechanical harvester (Apr. 2006)

In a further attempt to prevent poor budding, soils should be irrigated to field capacity before budding, except in cases where deficit irrigation might possibly require otherwise (VinPro Consultation Service, 2004).

Conclusion

The accumulation of winter cold differs from year to year, with the result that the physiological stage in which the vine finds itself at any specific moment, may also differ from one year to the next. Careful planning for optimal clean pruning and dormancy breaking application dates is therefore extremely important. Logging of budding dates may be useful in planning application dates for pruning and dormancy breaking.

Vines should be managed to obtain evenness as well as balance, so that they may have sufficient reserves for the winter rest period.

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References

ARCHER, E. & GOUSSARD, P.G. 1988. Strategie vir bekamping van vertraagde bot by wingerd. *Wynboer Tegnies*. 28, 4 - 6.

BUGER, J. & DEIST, J. 1981. *Wingerdbou in Suid-Afrika*. Second reprint. CTP Boekdrukkers, Cape Town. pp. 219 - 220, 242, 530.

GOUSSARD, P.G. 2002. *Dormansie*. Viticulture and Oenology Department, Stellenbosch University. p. 95.

HACKETT, S. & HOLZAPFEL, B., 2002. Factors underlying restricted spring growth in vineyards. *Australian Viticulture*. 6 (5), 76 - 81.

LOMBARD, J. 2003b. Rusbreek navorsing op Sultanina tafeldruiwe. Website. http://www.dfptresearch.co.za/Table%20Grapes/Rusbreek%20-%20sultanina%20J%20Lombard.htm. 27 August 2004.

LUDVIGSEN, K. 2004. Preparing your vineyard for mechanical harvesting. *The Australian & New Zealand Grapegrower & Winemaker*. 480 (January 2004), 37 - 40.

OR, E., NIR, G. & VILOZNY, I. 1999. Timing of hydrogen cyanamide application to grapevine buds. *Vitis*. 38 (1), 1 - 6.

OUTEUR ONBEKEND. 2004. Picking rod adjustment important to fruit quality. *The Australian & New Zealand Grapegrower & Winemaker*. 480 (January 2004), 42.

SMART, R., 2001. Good wines stem from balanced vines. *Australian & New Zealand Wine Industry Journal*. 16 (3), 53 - 54.

VINPRO (SA) KONSULTASIEDIENS. 2002. Wynboer Wenke vir Maart 2002. *Wynboer Tegnies*. 151 (February 2002), 5.

VINPRO (SA) KONSULTASIEDIENS. 2004. Wynboer Wenke vir Augustus. *Wynboer Tegnies*. 181 (August 2004), 6.

WIESE, J. 1988. Verbeter stokvorm met siaanamied. *Wynboer Tegnies* 28 (June 1988), 4 - 5.

An investigation into possible water savings using sub-surface irrigation (Part I) – Irrigation quantities, wetting patterns and root distribution

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Key words: Grapevine, irrigation, sub-surface, root distribution, clogging

Introduction

Although the Lower Orange River Region is situated in a summer rainfall region, the rainfall is too sparse to meet the water demands of grapevines grown there. Viticulture is therefore dependent on irrigation quotas varying from 15 000 m^3 per ha per annum in the Upington area, to 18 000 m^3 in the Kakamas area and further along the river. During abnormally dry seasons in the eastern parts of the country rainfall is insufficient to fill the dams supplying the vineyards along the Lower Orange River. When this happens, water restrictions may be imposed. Consequently there is enormous pressure on the viticultural industry to develop irrigation technologies to ensure sustainable production and the best possible grape quality using less water. In this regard it has already been proven that the same quantity of grapes can be produced using less water if the traditional full surface flood irrigation is replaced by irrigation in alternating rows or furrows (Myburgh, 2003). The question is whether even more water may be saved in the region if vineyards are irrigated using permanent irrigation systems, for example drip. As a considerable amount of water evaporates from the wet surface after irrigation, sub-surface drip should result in further savings if the surface soil does not get completely wet.

Sub-surface drip irrigation is already being used commercially in vegetable crops in the USA, sugar cane in Swaziland and pastures in South Africa (C. Malan, personal communication). In Australia 50mm drainage pipe is being used below the surface to irrigate vineyards that were previously subject to flood irrigation. The pipes are installed mechanically next to the vineyard rows. Heavier soils proved to be more suited to the drainage pipe than sandy soils (P. Clingeleffer, personal communication). Irrigation can also be applied sub-surface using porous pipe which is produced from recycled rubber. ARC Infruitec-Nietvoorbij tried to irrigate a vineyard near Oudtshoorn using the so-called Leaky Pipe®, but without success. Tests showed that the water delivery per unit length pipe was uneven and that the flow decreased when the pressure was increased to 100 kPa (Myburgh, unpublished data). The pores in the pipe walls are possibly compressed when the water pressure increases.

The purpose of this trial was to compare sub-surface with traditional above-ground irrigation methods, with a view to possible water savings, without reducing production levels and grape quality. In this article the practical aspects of application methods, wetting patterns and root distribution are discussed. Grapevine reaction with regard to growth, production and quality are discussed in a follow-up article.

Material and methods

The investigation was conducted near Upington using Sultanina (clone H5)/143B Mgt, which is cultivated for drying purposes. The vineyard was planted in 1998 in layered alluvial soil, classified as a Dundee form (Soil classification working group, 1991). The soil was deep ploughed before establishment using a wheel tractor to mix the layers, which usually restrict root distribution. The plant spacing was 3m by 1.8m and the vineyard was trained onto a gable trellis (Zeeman, 1981). Various methods of applying water sub-surface were compared to furrows and above-ground drip (Table 1). Although previous attempts to irrigate vines with porous pipe had failed, it was decided to run the test once again. Instead of using Leaky Pipe® as in the previous trial, this time Porous Pipe® was used for the trial. The latter was slightly sturdier, thereby reducing the possible compression of the pores. The wetting effectiveness of drippers with regard to flow rate, as well as the depth at which they are installed, also formed part of the investigation. All sub-surface irrigation lines were installed approximately 20cm from the vine row. Each irrigation treatment was repeated four times in a randomised block design. On each plot the 12 experiment grapevines were bordered by two grapevines on each side of the experiment rows, and on each side by two rows to prevent overlapping of treatment effects. The respective treatments were irrigated from the 1999/2000 season onwards, in other words just after establishment, until the 2003/04 season, using the different methods.

As a result of limited infrastructure, all the low flow rate drip treatments initially had to be irrigated in two instalments over two days. The storage

Table 1: Irrigation methods applied to compare the effectiveness of sub-surface irrigation with furrows and above-ground drip.

Treatment number	Irrigation system	Irrigation method Flow rate (L/hour)	Position
B1	Furrows, 0.8 m wide	N.a.	In vine row
B2	Drip, spaced 0.6 m	2.3 L/hour	Above-ground
B3	Drip, spaced 0.6 m	2.3 L/hour	15 cm Sub-surface
B4	Drip, spaced 0.6 m	2.3 L/hour	30 cm Sub-surface
B5	Drip, spaced 0.6 m	2.3 L/hour	45 cm Sub-surface
B6	Drip, spaced 0.6 m	3.5 L/hour	30 cm Sub-surface
B7	50 mm Ø Drainage pipe	N.a.	30 cm Sub-surface
B8	20 mm Ø Porous pipe	N.a.	30 cm Sub-surface

dam for the irrigation water used in the trial, which was pumped from a concrete canal on the experiment farm, was increased by about 30% during March 2002. Over the last two seasons it was therefore possible to wet all the low flow rate drip treatments in one irrigation instead of in two instalments. Despite the bigger storage capacity it was not possible to irrigate all the treatments on the same day. Soil water content was measured using a neutron moisture probe at 30cm, 60cm and 90cm depths. The probe was calibrated against gravimetric soil water content. The irrigation volumes were monitored using water meters. In the case of the furrows and drainage pipe the water levels in the dam were measured before and after irrigation to calculate the volume of water applied per irrigation. At the end of the trial samples of drippers were collected at all the drip irrigated plots. These drippers were subjected to flow measurement tests at the factory where they were manufactured. Intensive penetrometer measurements were taken five years after soil preparation, on all the experiment plots to characterise the physical condition of the soil. The measurements were done two days after irrigating the entire trial over the full surface. During the penetrometer study both the bulk density of the soil and the gravimetric water content were measured. Root distribution and density across the vineyard rows were determined for each site at the end of the trial.

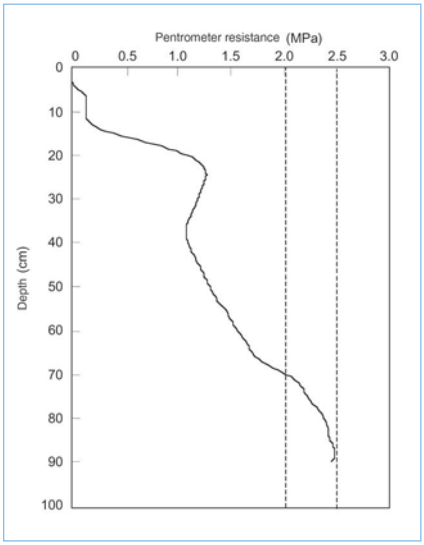

FIG 1: Average penetrometer resistance in alluvial soil at Upington five years after soil preparation. The dashed lines indicate soil strength at which root distribution starts to be restricted.

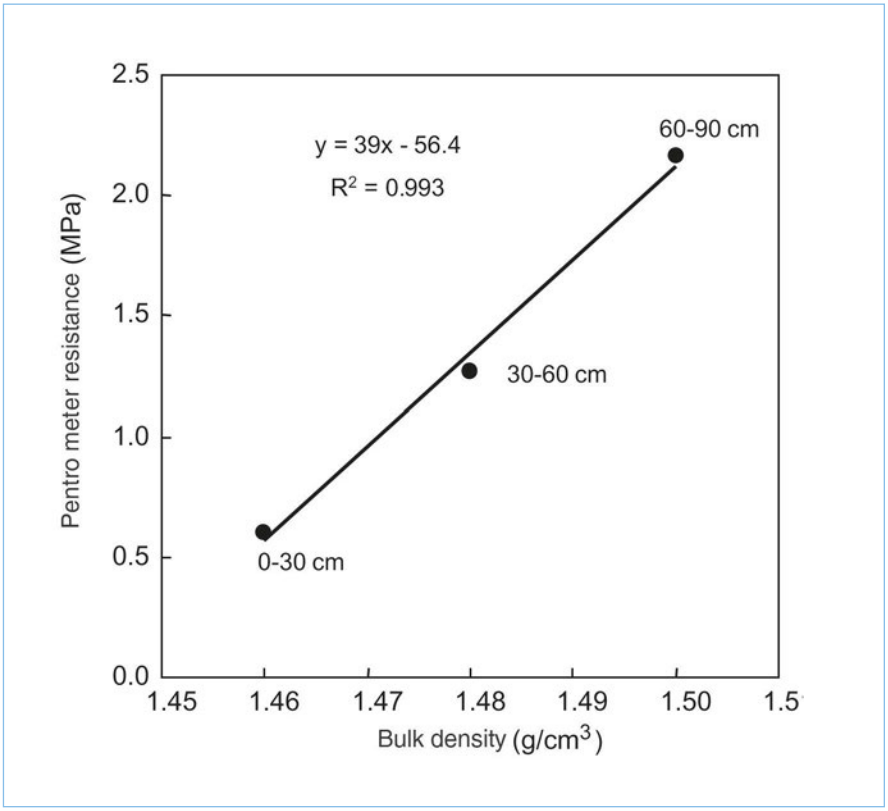

FIG 2: Relationship between penetrometer resistance and bulk density of alluvial soil at Upington five years after soil preparation.

Results and discussion

Soil physical condition: There were no differences in penetrometer resistance among the respective irrigation treatments. The slight compaction occurring between 20cm and 30cm, resulted from the cultivation required to level the beds for flood irrigation once the soil had been deep ploughed (Fig. 1). The average penetrometer resistance exceeded 2.0MPa at 70cm depth. This is in line with the soil preparation depth that is usually achieved by wheel tractors. However, the critical resistance of 2.5MPa at which root penetration starts to be restricted (Van Huyssteen, 1983 and references therein), was not exceeded up to 90cm. During the penetrometer study the average soil water content was 13.7%, 13.9% and 12.5% respectively over the 0-30cm, 30-60cm and 60-90cm depth increments. As the subsoil was slightly drier than the upper layers, this could have increased the penetrometer resistance compared to the upper layers. There was nevertheless a good correlation between penetrometer resistance and the bulk density of the soil (Fig. 2). The fact that the bulk density over the biggest part of the root depth was below 1.5g/cm^3, also indicates that there were no soil physical restrictions to root penetration up to 90cm (Van Huyssteen, 1988).

Pipe and dripper clogging: The porous pipe was entirely clogged after three seasons. Consequently the grapevines of this treatment were growing extremely poorly, and on the verge of dying back. It was decided to replace the porous pipe with 3.5L/hour above-ground drip to prevent the grapevines from dying. The treatment was changed in November 2001, and could therefore no longer be considered part of the field trial. Tests at the dripper factory showed that no clogging occurred in the above-ground drippers, while 12.5% of the sub-surface drippers were clogged (Table 2). There is no explanation why no dripper clogging occurred in drip lines at 45cm depth (B5). Microscopic investigations showed that the clogging was caused by grains of sand or root penetration. The latter occurred despite the application of trifluralin through the filter system, it being released into the water on an ongoing basis. In the drippers that did not become clogged, however,

Table 2: Clogging and flow rate of drippers installed sub-surface for six years, compared to above-ground drip.

Irrigation method	Clogged drippers (%)	Flow rate (L/hour)
B2 Drip, above-ground, 2.3 L/hour	0	2.30
B3 Drip, 15 cm sub-surface, 2.3 L/hour	12.5	2.49
B4 Drip, 30 cm sub-surface, 2.3 L/hour	12.5	2.36
B5 Drip, 45 cm sub-surface, 2.3 L/hour	0	2.30
B6 Drip, 30 cm sub-surface, 3.5 L/hour	12.5	3.70

Table 3: Monthly irrigation quantities (mm) as applied by different irrigation systems for the cultivation of Sultanina on alluvial soil at Upington. Data are the averages of the 2001/02, 2002/03 and 2003/04 seasons.

Mond	B1 Furrows	B2 Drip, 2.3 L/hour above-ground	B3-B5 Drip, 2.3 L/hour sub-surface	B6 Drip, 3.5 L/hour sub-surface	B7 Drainage pipe
September	31	33	32	39	33
October	78	56	56	69	63
November	98	96	92	107	85
December	95	101	92	123	104
January	87	88	85	114	93
February	79	75	74	69	65
March	54	46	41	51	54
April	44	40	37	39	42
May	22	37	38	42	28
June	26	36	37	43	26
July	46	40	42	50	47
August	33	55	51	66	34
Total	693	703	677	812	674

there was no significant decrease in the flow rate (Table 2). Under the given circumstances clogging will definitely decrease the lifespan of sub-surface drip compared to conventional above-ground drip. It was noted that the drainage pipe had a varying degree of silt accumulation. Clogging as a result of the silt may explain why the water bubbled to the surface during irrigation on some plots after three seasons.

Irrigation quantities: The average monthly irrigation quantities indicated in Table 3, are based on the full surface. In the case of sub-surface irrigation using 2.3L/hour drippers, an average of 3.7% less water was applied compared to above-ground drip. Since all four treatments irrigated with 2.3L/hour drippers, were irrigated from the same valve, the lower application was possibly caused by a measure of dripper clogging, which could have reduced the flow rate per unit surface. As a result of practical problems it was not possible to apply the same amount of water using the 3.5L/hour as with the 2.3L/hour drippers. Over the three seasons an average of 16% less water per annum was applied sub-surface using the 2.3L/hour drippers compared to the 3.5L/hour drippers (Table 3).

Soil water content: An example of the seasonal changes in the soil water content is indicated in Figure 3. For all treatments there was a gradual drying out over the warmest part of the season. The existing infrastructure and the fact that water was obtained on demand from a canal system, did not allow more than one irrigation per week. More regular irrigations would probably have prevented the gradual drying out. It was also clear that no water flowed through the sub-surface porous pipe during the first half of the particular season (Fig. 3). The soil water content of this treatment only started to increase once above-ground drip was installed towards the end of November 2001. As it was not practically possible to irrigate all the treatments on the same day, it was not possible to measure the soil water content just before and after the irrigations. The soil water content of the respective irrigation treatments could therefore not be properly compared. The soil water content of the drip treatments that were irrigated sub-surface, tended to be drier than the above-ground drip. This was probably due to clogging as discussed above. Compared to the drip treatments, there was also a tendency towards higher water content with furrows.

Wetting patterns: Measurement of soil water content directly after an irrigation on the drip line, as well as at a distance of 30cm and 60cm away in the work row, indicated that most of the water was applied in a 60cm wide strip with furrows as well as drippers. This distribution pattern was especially noticeable in the case of the drip treatments (Fig. 4). It was also clear that the soil water content was higher where irrigation was applied at 30cm and 45cm depths using drip lines. Wetting front detectors and tensiometers that were installed in a furrow and an above-ground drip plot at 30cm and 60cm depths respectively during the last season (2003/04), showed that during each irrigation a well-defined wetting front moved down to 30cm at the

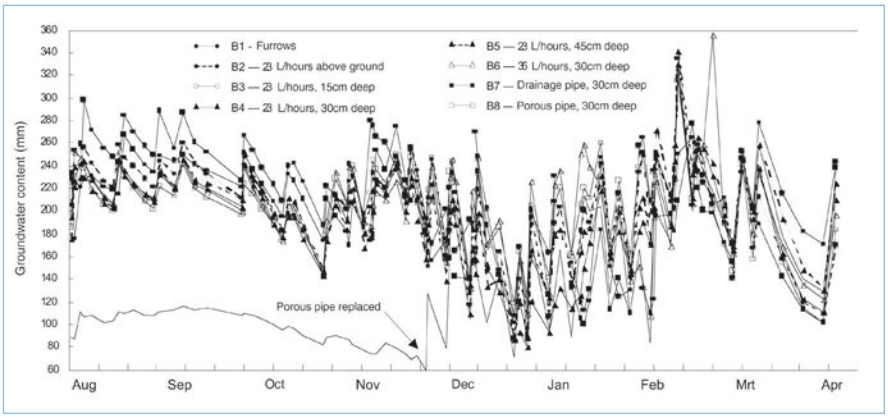

FIG 3: The effect of irrigation system on seasonal soil water content in alluvial vineyard soil as measured during the 2001/02 season at Upington. The porous pipe (B8) was replaced with 3.5 L/hour above-ground drip as a result of clogging at the end of November.

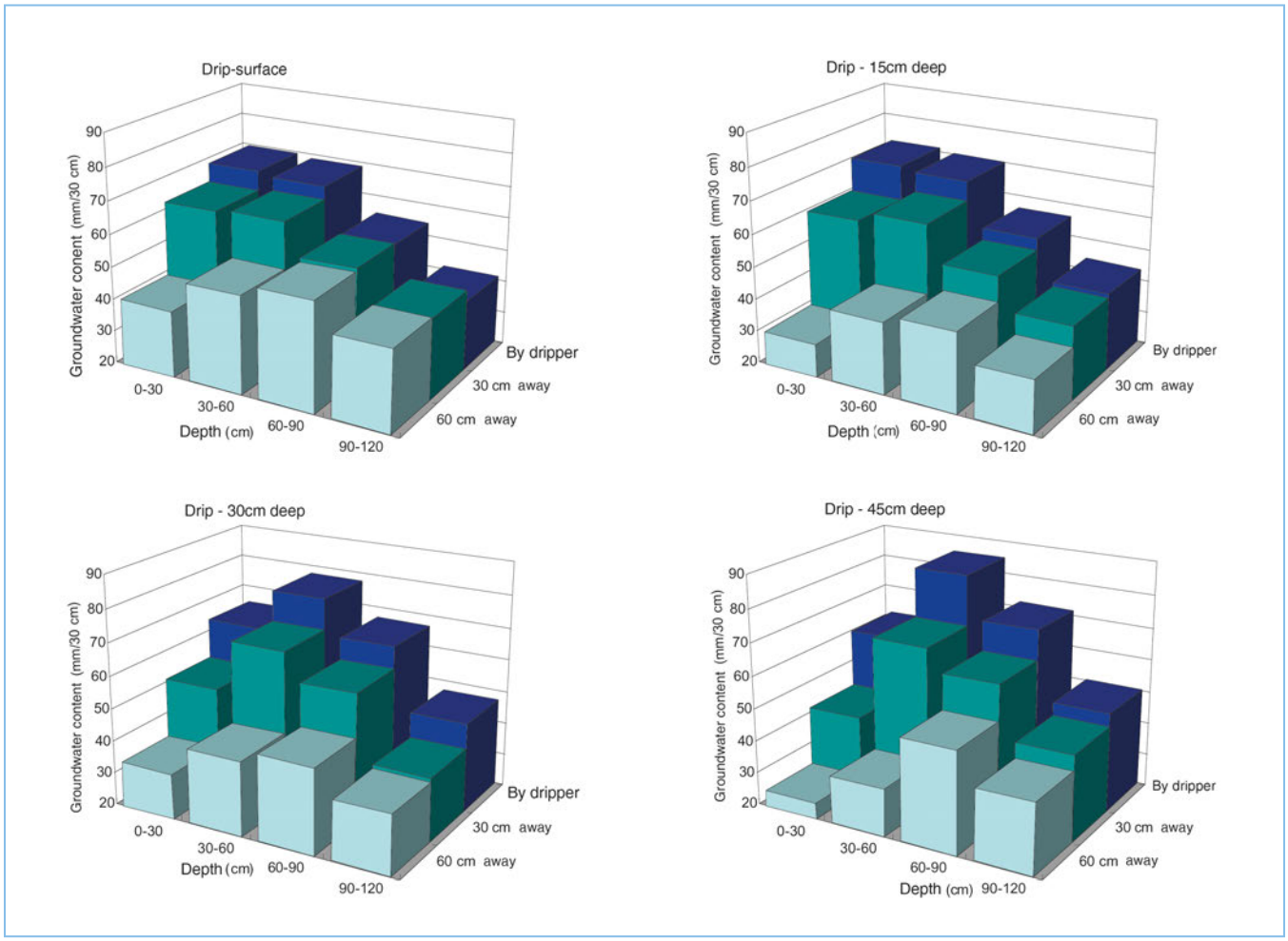

FIG 4: Wetting patterns around sub-surface drip at different depths compared to above-ground drip lines in alluvial soil as measured at the pea size berries during the 2001/02 season at Upington.

furrows (data not shown). According to the tensiometer readings soil wetting occurred down to 60cm at the drip plot, but even after an 18-hour irrigation, neither of the two depths had an obvious wetting front to which the detectors could react.

Root distribution: The root systems in all the treatments consisted mainly of fine roots. Despite limited wetting as discussed above, the fine roots occurred in all the treatments up to the middle of the work row (Fig. 5). Just after planting, two full surface flood irrigations were applied to ensure that the young grapevines grow properly. This could have caused the root systems to develop up to the middle of the work rows. Wetting of the total available soil volume by rain could also have contributed to the unexpectedly wide lateral root distribution. The absence of physical restrictions as discussed above, clearly did not restrict lateral, as well as vertical root distribution up to 90cm depth. However, the root concentration was higher away from the vine row where the sub-surface drip lines were installed (Fig. 5c). Root concentrations were considerably lower compared to the 3000 roots/m^2 in the small wetted soil volumes where drip irrigation was applied daily in pulses according to open hydroponic principles (Myburgh & Howell, unpublished data).

The root distribution patterns of all the replications of a specific treatment reacted the same. In the case of furrows, root concentration occurred to some extent in the wetted soil volume (Fig. 5a). A lesser amount of root concentration occurred where the above-ground drip (Fig. 5b) was used, compared to the sub-surface drip (Fig. 5c). There is no acceptable explanation for the absence of root concentration under the above-ground drip lines as well as around the drainage pipe (Fig. 5d). Where sub-surface drip was used to irrigate at 15 cm depth, there was not a high concentration of roots around the drip lines as at 30 cm and 45 cm depths (Fig. 6) either. As trifluralin was also applied by the above-ground drip, this substance may have enjoyed more widespread distribution in the top soil layer than in the subsoil, thereby limiting root development further away from the dripper lines. Higher drip flow rate (3.5L/hour) did not result in a significantly higher root concentration around the drip line compared to the 2.3L/hour drippers, installed at the same depth (Fig. 6b and 6d).

Conclusions

- Sub-surface irrigation did not hold any advantages over furrows or above-ground irrigation with regard to the amount of irrigation water and wetting patterns.
- In contrast with the cheaper fur-

rows, considerably less labour was required to apply the irrigations using the sub-surface methods.

- Under the given conditions, porous pipe clogged entirely and can therefore not be recommended.
- Drainage pipe may become clogged with silt in due course of time.
- Root invasion increases the risk of dripper clogging, despite the application of trifluralin.
- As a result of the clogging risk, sub-surface drip will not be the ideal irrigation method for vineyards along the Lower Orange River.
- If furrows are used to save water, the stream flow rates will have to be adjusted to the lengths and slopes of the beds, so as to ensure even wetting of longer vineyard rows.

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Literature references

Soil classification working group, 1991. Soil classification – 'n Taxonomic system for South Africa. Dept. Agricultural Development, Private Bag X144, Pretoria 0001.

Myburgh, P.A., 2003. Possible flood irrigation technologies to reduce water use of Sultanina grapevines in a hot, arid climate. S. Afr. J. Plant Soil 20, 1 - 8.

Van Huyssteen, L., 1983. Interpretation and use of penetrometer data to describe soil compaction in vineyards. S. Afr. J. Enol. Vitic. 2, 59 - 65.

Van Huyssteen, L., 1988. Soil preparation and grapevine root distribution – A qualitative and quantitative assessment. In: Van Zyl, J.L. (red). The Grapevine root and its environment. Technical communication No. 215. Dept. Agriculture & Water Supply, Pretoria, South Africa. pp. 1 - 15.

Zeeman, A.S., 1981. Oplei. In: Burger, J.D. & Deist, J. (eds). Wingerdbou in Suid-Afrika. Nietvoorbij, Stellenbosch, South Africa. pp. 185 - 201.

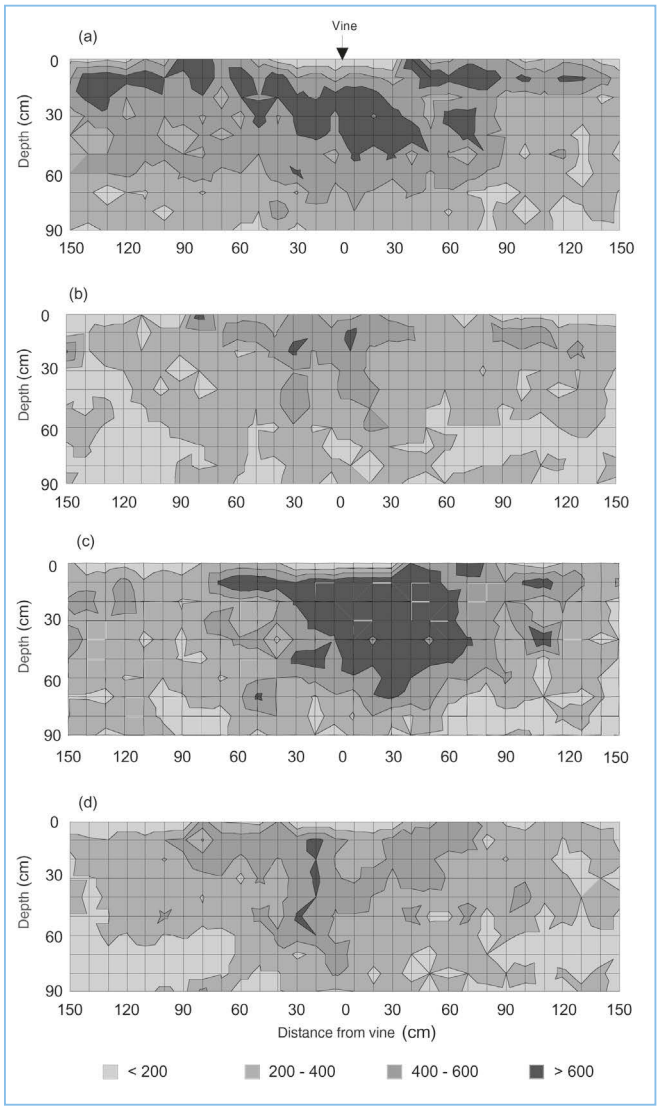

FIG 5: Distribution of fine roots under (a) furrows, (b) above-ground drip as well as around (c) sub-surface drip and (d) drainage pipe, both at 30 cm depth. The units indicate the number of roots per square metre.

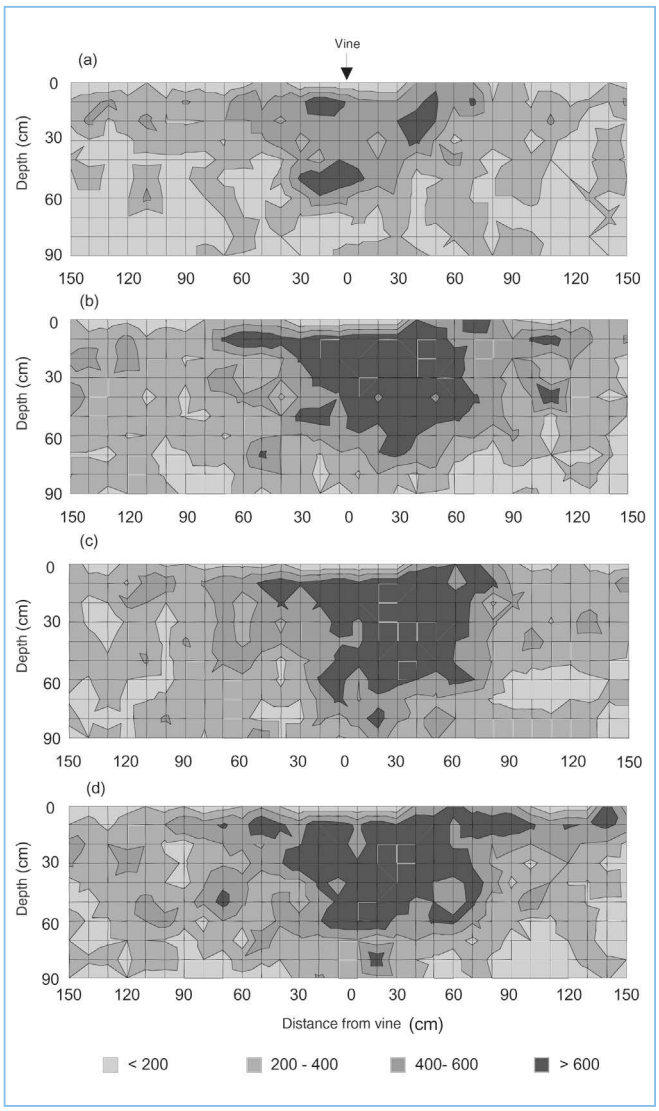

FIG 6: Distribution of fine roots around 2.3 L/hour sub-surface drip at (a) 15 cm, (b) 30 cm, (c) 45 cm depth and (d) 3.5 L/hour drip at 30 cm depth. The units indicate the number of roots per square metre.

An investigation into possible water savings with sub-surface irrigation (Part II) – Plant water stress, growth, yield and quality

Philip Myburgh, ARC Infruitec-Nietvoorbij, Stellenbosch

Key words: Grapes, irrigation, water potential, shoot growth, yield, raisin quality

Introduction

As a result of periodical droughts, producers in the Lower Orange River Region have to contend with water restrictions. The current Water Act also stipulates that licences to use water for agriculture will only be allocated if the water is being used effectively. What is more, the Water Allocation Reform (WAR) policy, in terms of which water may be allocated to communities that did not have access to it previously, is soon to be implemented by the Department of Waterworks and Forestry (Roux, 2006). The WAR policy will put additional pressure on existing water resources, and may possibly result in existing allocations being reduced. Consequently there will be more pressure on producers in future to use the available water more effectively. Sultanina (Sultana, Thompson's Seedless) is the most important cultivar in the Lower Orange River. If this cultivar experiences water deficits in summer as well as winter, it may seriously jeopardise grape yield and quality (Myburgh, 2003a; Myburgh, 2003b). Water deficits may also be detrimental to the vigour and yield of other cultivars such as Chenin blanc and Colombar, that are also cultivated in the region (Van Zyl & Weber, 1981; Van Zyl, 1984). It is therefore essential that any water saving practices do not impact negatively on the profitability of grapevines. The purpose of the project was to compare sub-surface irrigation methods on alluvial soils to more traditional above-ground methods with a view to possible water conservation, without reducing yield levels and grape quality.

Materials and methods

The field trial was carried out near Upington on Sultanina, which is being cultivated for the production of dried grapes. Different ways of applying water sub-surface were compared to furrows and above-ground drip (Table 1). The wetting effectiveness of drippers with regard to flow rate, as well as the depth at which it is installed, also formed part of the investigation. Each irrigation treatment was repeated four times in a randomised block design. On each trial site the 12 experiment grapevines were bordered by two grapevines at the ends of the experiment rows, as well as on both sides by two rows to prevent overlapping of treatment effects. The treatments were applied from the 2001/02 to 2003/04 seasons. More comprehensive information about the soil conditions, irrigation methods and quantities as well as other viticultural aspects have been published (Myburgh, 2007).

Plant water stress was quantified by measuring leaf water potential at various stages during the course of the trial. These measurements were taken either pre-dawn or at 12:00. On two occasions the daily course of the water stress was also measured. On 23 January 2004 leaf water potential over the course of the day was measured on a wet and dry experiment plot, respectively. Unlike the usual two-hourly intervals, the leaf water potential of three grapevines on each of the two plots was measured every 15 minutes from 09:45 to 18:00. Shoot growth was quantified by weighing the shoots at pruning. Yield was determined by weighing the total amount of grapes on each experiment plot and converting this figure to tons per hectare. Berry mass as well as sugar and acid content of the grapes were determined at harvest. Sun dried as well as leached raisins were made, after which the quality thereof was graded according to commercial standards at the processing plant in Upington. The water use efficiency was quantified in terms of the production water use efficiency (WUEp), which is defined as the grape mass (kg) produced per unit volume irrigation water (m3) (Myburgh, 2003c).

Table 1: Effect of irrigation method on leaf water potential in Sultania grapevines as measured at 12:00 on 25 November 2002.

Irrigation method	Leaf water potential (MPa)
T1 Furrows, 0.8 wide	-1.46a*
T2 Drip, above-ground, 2,3 L/hour	-1.59ab
T3 Drip, 15 cm sub-surface, 2.3 L/hour	-1.57ab
T4 Drip, 30 cm sub-surface, 2.3 L/hour	-1.60ab
T5 Drip, 45 cm sub-surface, 2.3 L/hour	-1.58ab
T6 Drip, 30 cm sub-surface, 3.5 L/hour	-1.53ab
T7 Drainage pipe, 30 cm sub-surface	-1.73b
T8 Porous pipe, 30 cm sub-surface	Treatment discontinued
Average	-1.58

* Values followed by the same letter in a column do not cliffer significantly ($p \leq 0.05$).

Results and discussion

Plant water stress: On 28 November 2001, just before the clogged porous pipe was replaced by above-ground dripper lines (Myburgh, 2007), the leaf

water potential of grapevines irrigated using furrows (T1), above-ground drip (T2), sub-surface drip (T4) and porous pipe (T8), was -1.47 MPa, -1.46 MPa, -1.44 MPa and -1.78 MPa, respectively during the warmest time of the day. There was consequently considerably more water stress in the grapevines that had been exposed to water deficits as a result of the clogged porous pipe. The leaf water potential in grapevines of the measured treatments was also lower than -1.2 MPa, which is generally accepted to be the water status at which negative effects on plant physiological processes start manifesting themselves (Williams et al., 1994). At about 12:00 on 25 November 2002 there was a tendency towards less water stress only in grapevines that were irrigated using furrows (Table 1). This indicated that furrows resulted in more effective wetting than the other methods. The scope of this investigation did not allow for an acceptable explanation why water stress in grapevines of the drainage pipe treatment on the day in question was significantly higher compared to T1.

Measurement of leaf water potential over the course of the day on 17 December 2003 once again showed that there were no significant differences in water stress between grapevines of the respective treatments during berry development (Fig. 1). Water stress in grapevines irrigated with drippers at 30cm depth (T4), was in fact significantly higher a few times in the course of the day compared to some of the other treatments. However, there is not a meaningful explanation why water stress was higher in T4 grapevines at the specific times. Leaf water potential of all the treatments was lower than -1.2 Mpa during the warmest time of the day, which indicates that there was in fact a degree of water stress that may have hampered the physiological activities during the day. Before sunrise leaf water potential of all the treatments was higher than -0.4 MPa (Fig. 1). This was also an indication that severe negative effects on plant physiological processes had not yet manifested themselves (Williams et al., 1994). Consequently there was sufficient water in the soil for the water status in the grapevines to recover during the night.

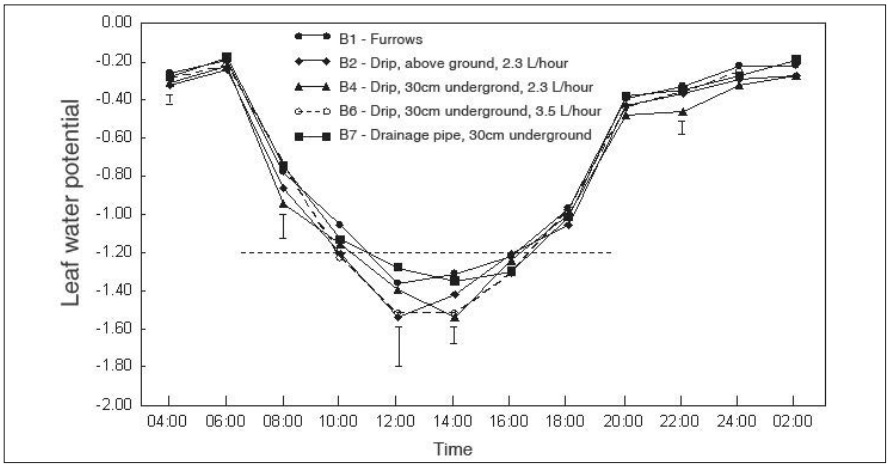

FIG.1 Effect of different irrigation methods on daily course of leaf water potential in Sultanina in alluvial soil as measured on 17 December 2003 at Upington.

During the 2003/04 season leaf water potential before sunrise was measured shortly before the harvest on 22 January 2004. The water status in grapevines of all the treatments varied from -0.21 MPa to -0.28 MPa and there weren't any significant differences between any treatments (data not shown). The high values indicated that the water status in the grapevines also recovered during ripening in the course of the night. The next day the intensive measurements showed that for the most part of the day, water stress in grapevines in the wetter soil was lower than in the ones in the drier soil (Fig. 2). However, leaf water potential had an oscillating tendency in the dry as well as the wet plot during the warmest part of the day. Seeing that the atmospheric conditions did not fluctuate over short periods in the course of the day (Fig. 3), the oscillations were probably caused by partial stomatic closure. The regulation of the water stress was so effective that the stress in grapevines on the drier plot was even lower in the course of the afternoon than stress on the wetter plot. It is also clear that regulating did not cause a linear increase in water stress to coincide with the decrease in air moisture over the course of the day, or with the increase in vapour pressure deficit (VPD) (Fig. 3). The aforegoing explains to a certain extent why there were generally no prominent differences in water status between treatments. It also proves in no uncertain terms that Sultanina is able to prevent serious water stress under warm, dry conditions, and is therefore able to perform well in the Lower Orange River region.

Table 2: Effect of different irrigation methods on vegetative growth, yield and berry mass of Sultanina in alluvial soil at Upington. The data are averages from the 2001/02, 2002/03 and 2003/4 seasons.

Irrigation method	Shoot mass (t/ha)	Yield (t/ha)	Berry mass (g)
T1 Furrows, 0.8 m wide	2.6a*	40.2a	2.0a
T2 Drip, above-ground, 2.3 L/hour	2.3a	36.2a	1.9ab
T3 Drip, 15 cm sub-surface, 2.3 L/hour	2.1a	35.6a	1.9ab
T4 Drip, 30 cm sub-surface, 2.3 L/hour	2.2a	34.7a	1.9ab
T5 Drip, 45 cm sub-surface, 2.3 L/hour	2.6a	32.1a	1.9ab
T6 Drip, 30 cm sub-surface, 3.5 L/hour	2.5a	41.0a	2.0a
T7 Drainage pipe, 30 cm sub-surface	2.5a	35.6a	1.8b
Average	2.4	36.5	1.9

* Values followed by the same letter in a column do not differ significantly ($p \leq 0.05$).

Vegetative growth: The average growth vigour was comparable to that of Sultanina which was also irrigated

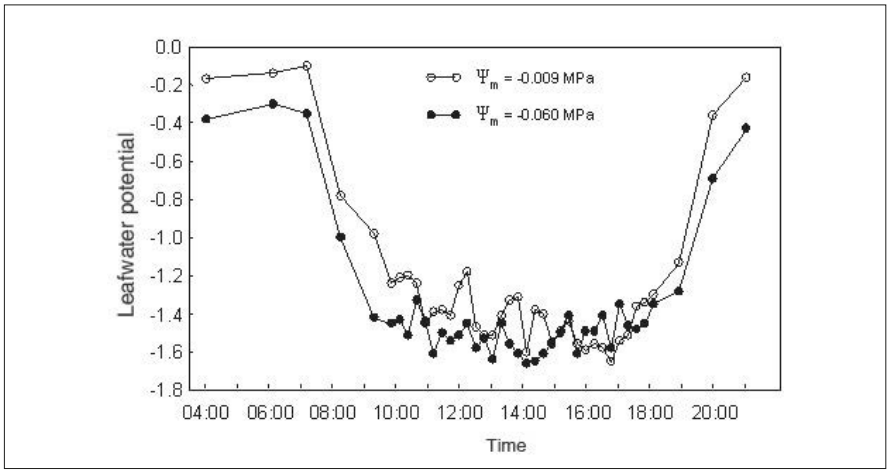

FIG.2 Daily course of leaf water potential in Sultanina in moist soil (ψ_m = -0.009 MPa) and drier soil (ψ_m = -0.06 MPa) as measured shortly before harvest on 23 January 2004 at Upington.

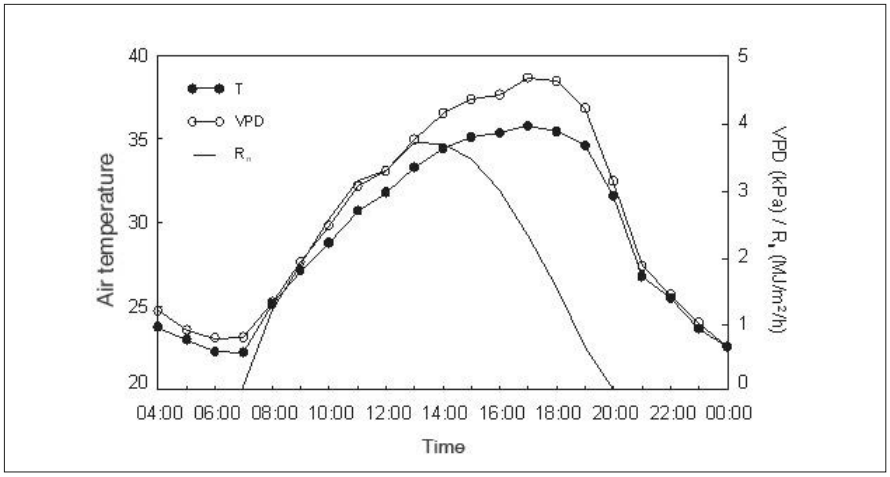

FIG.3 Air temperature, vapour pressure deflict (VPD) and nett incoming radiation (R_n) as measured on 23 January 2004 at Upington.

using furrows in a previous investigation, but lower compared to grapevines that were flood irrigated over the total surface (Myburgh, 2003c). The shoot growth was also comparable to that of Sultanina (clone H4) that received micro-sprinkler irrigation twice weekly on sandy soil away from the river (Myburgh, 2003a). Although there were signs of water stress during the day, grapevines of all the treatments were vigorous enough for the development of sufficiently strong bearing canes. Over the three seasons grapevines irrigated using the different permanent systems (T2 to T7), showed the same vigour compared to the furrow irrigation (T1) (Table 2).

Yield: In general good berry mass (ca. 1.9 g/berry) for raisin production was obtained by all the irrigation methods (Table 2). This was even higher than the 1.7 g/berry where Sultanina on sandy soil away from the river was irrigated twice a week using micro-sprinkler irrigation which wetted the total surface (Myburgh, 2003a). Slightly higher water stress that occurred during the first two seasons probably caused the average berry size of grapes that were irrigated sub-surface using drainage pipe (T7), to be smaller than berries of grapevines irrigated using furrows (T1). Where water was applied sub-surface with higher flow rate drippers (T6), the bigger berries could possibly be ascribed to more water being applied (Myburgh, 2007). The rest of the sub-surface irrigation treatments did not have a significant effect on average berry mass compared to furrow irrigation or aboveground drip.

Average yields obtained with the H5 clone over three seasons, were relatively high compared to the long term average of approximately 20 t/ha for Sultanina in this particular region. The yields were also considerably higher compared to that of Sultanina in alluvial soil irrigated over the total surface (Myburgh, 2003c). However, the latter results were obtained with less fertile "Orange River" Sultanina. The yields were comparable to Sultanina (clone H4) that received micro-sprinkler irrigation twice weekly on sandy soil away from the river (Myburgh, 2003a). None of the respective irrigation treatments had a significant effect on yield, however (Table 4). Except for the high flow rate drippers (T6), more or less the same quantity of water was given in all the treatments (Myburgh, 2007). The tendency to higher yield with the furrows was therefore possibly due to the fact that the irrigations were given in one application throughout. This resulted in more effective wetting compared to the other treatments (Myburgh, 2007). Where irrigation with higher flow rate drippers was applied sub-surface (T6), the tendency to higher yield could possibly be ascribed to more water. Seeing that most of the water and root distribution patterns were comparable (Myburgh, 2007), bigger, more effective root systems could not have caused the tendency to higher yields of T1 and T6 compared to some of the other treatments.

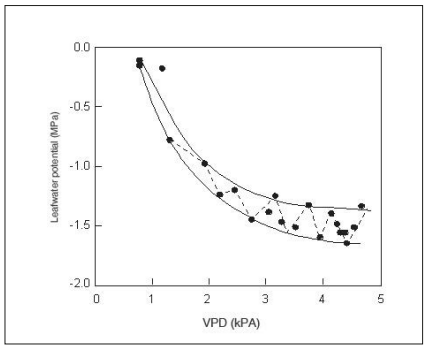

FIG.4 Relationship between vapour pressure deflict (VPD) and leaf water potential in Sultanina in alluvial soil where the matric potential was -0,009 MPa. (Curves were fitted by eye and the broken line indicates the time sequence of the measurements)

Tabel 3: Effect of different irrigation methods on raisin quality grading of Sultanina in alluvial soil at Upington. Sun dried raisins data are the averages of the 2001/02 and 2003/04 seasons, whereas leached raisins data are the averages of the 2001/02 and 2002/03 seasons.

Irrigation method	Sun dried (%)			Leached (%)		
	Choice	Standard	Industrial	Choice	Standard	Industrial
T1 Furrows, 0.8 m wide	54a*	24abc	8a	69a	16a	7a
T2 Drip, above-ground, 2.3 L/hour	47a	24abc	13a	54a	28a	9a
T3 Drip, 15 cm sub-surface, 2.3 L/hour	66a	13bc	10a	53a	28a	8a
T4 Drip, 30 cm sub-surface, 2.3 L/hour	49a	24abc	15a	62a	17a	10a
T5 Drip, 45 cm sub-surface, 2.3 L/hour	55a	12c	13a	57a	24a	8a
T6 Drip, 30 cm sub-surface, 3.5 L/hour	49a	28ab	10a	70a	13a	8a
T7 Drainage pipe, 30 cm sub-surface	45a	36a	8a	67a	19a	7a
Average	52	23	11	62	21	8

* Values followed by the same letter in a column do not offer significantly ($p \leq 0.05$).

Tabel 4: Effect of irrigation method on production water use efficiency (WVE_p) of Sultanina in alluvial soil at Upington. Data are the averages of the 2001/02, 2002/03 and 2003/04 seasons.

Irrigation method	Irrigation applied (m^3/ha/year)	WCE (kg/m^3)
T1 Furrows, 0.8 m wide	6930	5.8
T2 Drip, above-ground, 2.3 L/hour	7030	5.2
T3 Drip, 15 cm sub-surface, 2.3 L/hour	6770	5.3
T4 Drip, 30 cm sub-surface, 2.3 L/hour	6850	5.1
T5 Drip, 45 cm sub-surface, 2.3 L/hour	6720	4.8
T6 Drip, 30 cm sub-surface, 3.5 L/hour	8120	5.1
T7 Drainage pipe, 30 cm sub-surface	6740	5.3
Average	7020	5.2

Despite the gradual drying out of the soil during the warmest part of the season (Myburgh, 2007), yields were considerably higher than the average for dried grape vineyards along the Lower Orange River. On the other hand the gradual drying out of the soil could have restricted vigorous shoot growth. The vineyard was to a certain extent irrigated according to a regulated deficit irrigation strategy. It seems therefore that it may be possible to prevent the vigorous shoot growth that occurs on the alluvial soils, in particular when such an irrigation strategy is followed, without sacrificing yield. If deficit irrigation is applied, however, all soil and viticultural management practices will have to be optimal.

Sugar and acid content in the must: The average sugar and acid content of the must were 21.5°B and 5.8 g/L, respectively, over the three seasons. The different sub-surface irrigation treatments did not have a significant effect on sugar and acid content in the must compared to furrow irrigation or above-ground drip during any of the three seasons (data not shown). Despite the relatively high crop load and signs of water stress during the day, none of the treatments caused problems with regard to an increase in sugar. During all three seasons the grapes of all the treatments could be harvested on the same day.

Raisin quality: During the 2002/03 season the sun dried raisins desiccated to such an extent during a heat wave in the course of a weekend that they could not be properly graded. The leached raisins were damaged by rains during the 2003/04 season to such an extent that they could not be graded either. For both sun dried and leached raisins data could therefore only be collected over two seasons. The respective sub-surface irrigation treatments did not have a significant effect on average percentage choice grade sun dried or leached raisins compared to furrows or above-ground drip during either of the two seasons (Table 3). There is no acceptable explanation why sub-surface drip at 2.3 L/hour at 15cm and 45cm depths resulted in less standard grade raisins compared to some of the other treatments.

Water use efficiency: The total amount of irrigation water that was applied to all the treatments on average per annum (Table 4), was considerably lower than the 15 000 m3/ha to 18 000 m3/ha quotas that are currently allocated to producers along the Lower Orange River. The average production water use efficiency of Sultanina was considerably higher (Table 4) compared to the approximately 2 kg/m3 where flood irrigation was applied over the total surface (Myburgh, 2003a). Drip irrigation, be it above-ground or sub-surface, did not improve the production water use efficiency compared to furrows (Table 4). It should be borne in mind, however, that flood irrigation applied in short beds is more effective than when applied in long beds. It could therefore be that the short furrows that were used in the trial were not entirely representative of the situation in practice and may have benefited growth and yield ahead of drip irrigation.

Conclusions

It is fascinating that the minimum leaf water potential over the hottest part of the day was below -1.2 MPa on all the days in question, but that sufficient vigour and above-average yields could be maintained while retaining quality. The only exception was where the clogged porous pipe caused serious water deficits. Similar values were also measured previously in Sultanina in alluvial soil (Myburgh, 2003c). This indicated that the water stress threshold value of -1.2 MPa could possibly have been too high for dried grape

Sultanina along the Lower Orange River. A value of -1.8 MPa on the other hand showed that the grapevines experienced serious water deficits. It may therefore be more realistic to use a threshold value of -1.5 MPa as an indication that irrigation is necessary. With furrows or drip irrigation considerable water savings, while retaining above-average yield and acceptable raisin quality, are indeed possible for the cultivation of grapes on the alluvial soils of the Lower Orange River. Drip irrigation, be it above-ground or subsurface, did not offer additional water savings compared to furrows.

Recommendations

- It will be more realistic to use a water stress of -1.5 MPa instead of -1.2 MPa as an aid to irrigation scheduling for Sultanina that is cultivated for dried grapes along the Lower Orange River.
- Vineyards in alluvial soil may be irrigated successfully with drippers to save water.
- Furrows may also be used, but bed slopes and stream flows should be adjusted accordingly.
- Previous research results have already indicated that a switch from full surface flood irrigation to furrows may be successful provided the soil water content is carefully monitored on an ongoing basis to prevent water deficits.
- If the capital expenditure is taken into account, furrows may be more cost effective than drip irrigation.

Acknowledgements

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Literature references

Myburgh, P.A., 2003a. Responses of Vitis vinifera L. cv. Sultanina to level of soil water depletion under semi-arid conditions. S. Afr. J. Enol. Vitic. 24, 16 - 24.

Myburgh, P.A., 2003b. Responses of Vitis vinifera L. cv. Sultanina to water deficits during various pre- and post-harvest phases under semi-arid conditions. S. Afr. J. Enol. Vitic. 24, 25 - 33.

Myburgh, P.A., 2003c. Possible flood irrigation technologies to reduce water use of Sultanina grapevines in a hot, arid climate. S. Afr. J. Plant Soil 20, 1 - 8.

Myburgh, P.A., 2007. 'n Ondersoek na moontlike waterbesparing met ondergrondse besproeiing I - Besproeiinghoeveelhede, benattingpatrone en wortelverspreiding. Wynboer, February 2007, 12 - 16.

Roux, A., 2006. Soil moisture measurement integral to scheduling. SA Irrigation, June/July 2006, 5.

Van Zyl, J.L., 1984. Response of Colombar grapevines to irrigation as regards quality aspects and growth. S. Afr. J. Enol. Vitic. 5, 18 - 28.

Van Zyl, J.L. & Weber, H.W., 1981. The effect of various supplementary irrigation treatments on plant and soil moisture relationships in a vineyard (Vitis vinifera var. Chenin Blanc). S. Afr. J. Enol. Vitic. 2, 83 - 99.

Williams, L.E., Dokoozlian, N.K. & Wample, R., 1994. Grape. In: Schaffer, B. & Anderson, P.C. (eds.). Handbook of environmental physiology of fruit crops, Vol I, Temperate crops. CRC Press, Boca Raton, 85 - 133.

Nematodes in vines: Practical guidelines for the short- and longterm control of nematodes

Sheila Storey

Compiled by Sheila Storey, Nemlab, on behalf of the Decidious Fruit Industry

Introduction

Nematodes are microsopic worm-like organisms that attack the roots of plants. Damaged roots result in a reduced uptake of nutrients and water.

Vines are attacked by various nematodes, of which the root-knot nematode is the most important. Due to the large-scale use of root-knot nematode resistant rootstocks, the characteristic galls of root-knot nematode are absent. The damage caused by other nematodes is not visible, both above and below ground. Dagger and ring nematodes are becoming an increasing problem in vines, and control of the latter is problematic.

There are several reasons for the increase in nematode problems over the last number of years. The first reason is the greater awareness of nematode damage. A second is the increasing pressure to re-use soils. The most important reason, however, is the fact that within four months of the removal of vines or stone and pome fruit trees, vines are again established on the same soils. Associated herewith is the fact that few producers consider fumigating the soil, or realise how important it sometimes is. The treatment of new vines after establishment then often gives unsatisfactory results.

Different nematodes attack different fruit types (see Table 1).

Nematodes are divided into two groups, depending on their feeding habits, viz. endo- and ectoparasites (Table II).

Infestation sources

There are three possible infestation sources, viz. water, plant material and soil.

Water

Water originating from fast-flowing rivers with significant agricultural activity (particularly vegetable production) can act as a nematode infestation source. Such water is however a minor source of infestation in comparison to the other two sources. The percentage of nematodes that originates from water is minimal. The build-up of nematodes in the soil is thus slow. If planting is commenced in relatively clean soil, then the vines will 'resist' this build-up of nematodes.

Plant material

Only rooted plant material can be a possible source of infestation. Such infestation is particularly true of the migrating endoparasite, root-lesion nematode and the obligate sedentary endoparasite, root-knot nematode. Both nematode types live in the roots. It has also been found that ring and dagger nematodes, with their long stylets, are inclined to cling to roots and can thus be transported together with plant roots.

The current certification scheme requires that plant material must be visibly free of nematode infestation. Symptoms of only one nematode i.e. the root-knot nematode, are visible.

Apart from the current certification scheme, there are guidelines in place which try to ensure that nurseries provide reasonably clean plant material. The plant material is thus unlikely to be the source of nematode problems in grapevines.

Heeling in soil of producers

Heeling in soil of both nurseries and producers should be monitored and, if necessary, appropriate action must be taken. The same rules, as for all soils where planting will take place, apply here (see Control: Before planting/ establishing new vines).

Soil

The soil is the most important infestation source. Infestation in the soil is deter-

Table 1: The host-nematode relationship of the most important nematodes on fruit.

	Peaches	Prunes	Apricots	Apples	Pears	Vine
Root-lesion nematode*	xx	xx?	x	xx	x	x
Dagger nematode	xx	xx	x	xxx	xx	xxx
Spiral nematode				x	x	
Stubby-root nematode	x			xx	xx	x
Pin nematode			x	x		
Root-knot nematode*(**)	xxx	xxx	x?			xxx
Ring nematode	xxx	xxx	xxx			xxx

xxx Very important, can cause severe damage, occurs commonly
xx Important, can sometimes cause severe damage when the counts are high, occurs commonly
x Seldom causes a problem, little knowledge available regarding the extent of damage caused
* Endoparasites
** Except for root-knot nematode-resistant rootstocks
? Insufficient evidence to establish host status

Table 2: Endo- and ectoparasitic nematodes on vines.

Endoparasites (feed within the root)	**Ectoparasites** (feed outside on the root)
Root-know nematode	Ring nematode
Root-lesion nematode	Dagger nematode
Citrus nematode	Stubby-root nematode
	Spiral nematode
	Pin nematode
	Sheath nematode

mined by previous crops, cover crops, weeds or natural vegetation (fynbos) that were present in the soil. Should any of these plants have been a host for the range of nematodes that occur on vines, then the population will increase rapidly in the presence of vines and subsequently cause damage.

Monitoring

Always analyse both soil and root samples to determine the infestation in the vines.

Prior to establishment

Samples should be taken while a crop is still present, i.e. before trees, vines, or other previous crops are removed from the soil. When the host plants are removed, the nematodes revert to an egg stage, which then makes it impossible to determine populations at a commercial level.

Shortly after establishment

Since most nematodes only hatch in the presence of root exudates, it takes approximately four months before nematode numbers are high enough to be observed.

Established vineyards

Samples can be taken throughout the year. Populations are highest in the summer months and decline as the soil becomes colder. Recommendations based on the results are adjusted according to the time of sampling. Soils which are unusually wet or dry should preferably not be sampled.

Water

The monitoring of water is impractical and is not recommended.

Control: Prevention is better than contorl!

The result of the nematode analysis determines which control measures are applied.

Before planting/establishing new vines

It is of critical importance to minimise the number of nematodes before planting new vines. Identify at least one (or more) year(s) in advance which blocks are going to be re-established. Then determine the risk-level of the soil in terms of nematode infestation by having the soil analysed (see Monitoring). It is particularly old vine and stone fruit soils that cause problems because the same range of nematodes attack these crops (Table 1). Other crops that hold possible risks include most vegetables, cucurbits, Port Jackson, Acacia, Black Wattle and rye. Except for rye, most of these plants are excellent hosts for root-knot nematodes. Rye is a good host for root-lesion nematodes.

Always remove as many of the old roots of the previous crop as possible. It is particularly the endoparasitic root-lesion and root-knot nematodes that find shelter in the roots.

There are four control options that can be considered at this stage, and they are largely determined by the infestation in the soil and time period between plantings:

The existing crop can be treated to reduce the number of nematodes in the soil. More than one treatment is often necessary and this option must be evaluated timeously (about two years before the new planting). This option should particularly be considered if re-establishment is planned for the same year.

Where root-knot nematode numbers are particularly high and fumigation is not an option, resistant rootstocks must be considered. Most vines (resistant

Table 3: Nematode resistance on certain vine rootstocks.

Rootstock	**Root-know nematode** M incognita	**Ring nematode** M xenoplax	**Dagger nematode** X americanum	**Root-lesion nematode** P vulnus	**Citrus nematode** T semipenetrans
Ramsey	R			R	R
SO4	R				
Dog Ridge	R	S	S	MR	MR
Freedom	R	S	S	MR	MR
Harmony	R	S	S	S	S
Paulsen 775	R				
Richter 99	MR	S	S	S	MR
101-14 Mgt	MR				
143 B Mgt	MR				
Paulsen 1103	MR				
Richter 110	MS				
US 8-7	MS				
Paulsen 1447	MS				
Metallica	S				
140 Ruggeri	S				
Jacquez	S				

Scale: R = resistant; MR = mildly resistant; MS = mildly susceptable; S = susceptable

rootstocks excluded) are exceptionally susceptible to root-knot nematodes (Table III). This resistance only applies to root-knot nematodes and the vines will still be attacked by other nematodes.

A rest period of one year, but preferably longer (3 years), should be considered with the establishment of a poor or non-host crop in a rotation system. Non-hosts include *Tagetes* and *Crotalaria* spp as well as *Eragrostis* for long-term establishment. Crops considered weak hosts include oats, triticale and wheat. Rye must be avoided where root-lesion nematode occurs. Much research still needs to be done to determine the extent of susceptibility of these crops to various nematodes. This is one of the large gaps in our knowledge base. It is important to conduct an analysis of the nematode infestation again, just before the crop dies or is ploughed in.

If the nematode population is exceptionally high, and no fallow period is planned, it is sometimes essential to fumigate the soil before the new vines are established. Some producers believe that chemical treatment after establishment gives the same results as fumigation. This is however not true. Fumigation can only be carried out prior to establishment. The following fumigants can be considered: methyl bromide; 1,3-D (Telone II); ethylene dibromide (EDB); furfural (Protect) and metham sodium (Herbifume). Each of these fumigants has very specific requirements to guarantee successful treatment. The requirements include, among others, temperature, soil type, moisture, organic material content, etc. Establish thus timeously what the requirements of each product are. The requirements are available from Nemlab or the agricultural chemical companies.

- Other possible options include solarisation and biofumigation.
- *Solarisation* is a method to control soil-borne organisms and pathogens through the use of raised soil temperatures. The temperature is increased by placing a thin, transparent poly-ethylene plastic over a moist soil surface. Solarisation reduces the nematode population drastically, but will not totally eradicate it.
- *Biofumigation* or biological fumigation is a technique that uses certain plants' own protection functions to control a range of organisms and pathogens, including fungi, bacteria, nematodes, insects and certain weeds. The plants produce special volatile compounds, of which glucosinolates are the most important. Plant types particularly suitable for biofumigation include the family Brassicaceae (cabbage, cauliflower, broccoli, kale, canola and mustard), and the family Moringaceae (horseradish and certain types of radishes). The plants are harvested immature, chopped fine, and worked into the soil. The land then lies fallow for 10 – 14 days before the next crop is planted.

Do not try to solve a nematode problem with chemicals after establishment. This is a short-sighted approach.

Shortly after establishment

It is extremely important that populations are limited to the minimum during this stage. Roots that are damaged in this young stage do not recover easily and will never reach their full potential. If the result of nematode analysis recommends chemical treatment after establishment, the first treatment can be applied 6 weeks after planting, and followed up 2 months later with a second application, if necessary. Thereafter, monitor the populations on a regular basis.

Currently (August 2006) aldicarb (Temik), cadusafos (Rugby) and fenamiphos (Nemacur, Fenamiphos) are registered on vines. The recommended dosages prescribed on the label must be used. It is important to wash the nematicide in with sufficient water (10 – 20 mm). It is also important that the planting row or ridge is free of cover crops or weeds at the time of application.

Established vinyards

Always first determine the level of infestation before any action is taken against nematodes. The result of the nematode analysis will indicate the number of treatments. The treatments must commence just before root growth peaks in the spring and autumn. The optimum stage for treatment is within 30 days after harvest, followed by the period just before and after bud-burst. Treatments can be applied throughout the year, but the above-mentioned times give the best results.

It is important that the period between the follow-up treatments is kept to 6 months. The year-on-year treatments are not successful. The ring and dagger nematodes are more difficult to control and it thus takes longer to obtain a reduction in their numbers. It is unnecessary to eradicate nematodes. Try to reduce nematode numbers to acceptable levels.

Currently (August 2006) aldicarb (Temik), cadusafos (Rugby) and fenamiphos (Nemacur, Fenamiphos) are registered on vines. The recommended dosages prescribed on the label must be used. It is important to wash the nematicide in with sufficient water (10 – 20mm). It is also important that the planting row or ridge is free of cover crops or weeds at the time of application. Due to the possibility of accelerated microbial degradation, it is important to alternate the nematicides.

Water

Water cannot be treated chemically, it can however be filtered. Any filter, including sandfilters, will give a measure of control. Filters with 5 µm pores are required to totally exclude nematodes from water, but this is impractical in the vineyard situation.

The infestation from rivers can also be drastically reduced by pumping water into dams. The water should preferably stand for 48 hours to give the nematodes time to settle, and then water must be drawn from the surface.

General Root Health

It is advisable to promote root growth with the use of a root stimulant. A mulch on top of the soil or the addition of any organic material will be of great benefit. None of these additions will control high nematode numbers, but will encourage root growth and natural enemies (beneficial soil organisms), thereby reducing damage by nematodes. Nematode numbers will then decline over the long-term.

The guidelines as set out above are largely based on experience. Due to the lack of sufficient scientific knowledge, it is not possible to confirm these guidelines with scientific evidence.

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The effect of cover crops on ants and mealy-bugs in vineyards

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Pia Addison

Biological control of the vine mealybug (*Planococcus ficus*) cannot take place without ant control. Ants feed on the honeydew excreted by mealybugs and thereby prevent small parasitic wasps and predatory beetles from attacking the mealybugs (Kriegler & Whitehead, 1962). In the Western Cape there are primarily four ant species that are associated with vine mealybug: the Argentine ant (*Linepithema humile*), two species of pugnacious ant (*Anoplolepis custodiens* and *A. steingroeveri*) and the cocktail ant (*Crematogaster peringueyi*) (Addison & Samways, 2000). Ants are controlled effectively using chemical stem barriers (Addison, 2002). This method of control allows the ants to remain on the ground where they are effective predators of other insects, but prevents them from entering the vine canopy to forage on honeydew.

Natural enemies have been found to use cover crops as alternative refuges and so enhance biological control in agricultural systems (Tedders, 1983; Altieri & Schmidt, 1985; Bugg & Waddington, 1994 and Hoffmann, 2000). Cover crops, by reducing dust levels in vineyards, may protect natural enemies from exoskeleton abrasion (Pettigrew, 1998). In light of this, and the growing interest among producers to plant cover crops, this study was conducted to determine what effect various cover crops have on local pugnacious ant infestations and mealybug parasitoid populations and so in turn affect mealybug populations in vineyards in the Western Cape.

A mealybug infested Chenin blanc vineyard in the Bonnievale area, 1.5ha in size, was selected. Three cover crop treatments, namely grazing vetch (*Vicia dasycarpa* Ten.) and triticale (*Triticale* v. Usgen 18), controlled chemically from bud break, as well as dwarf fescue (*Festuca arundinaceae* v. Cochise), slashed throughout the growing season of the vines, were compared to a control treatment in which a standard chemical and mechanical weed control programme was followed. Monitoring of insect populations took place between June 2001 and March 2003. The following data was collected: Ant activity on the soil surface, nest entrance counts, ant and mealybug infestations in the vine canopy, mealybug parasitoid activity. The data was analysed using Analysis of Variance (ANOVA) and Least Significant Differences (LSD) calculated to compare treatments. Soil temperature and moisture readings were taken hourly for the duration of the trial at 10 cm and 30 cm depths. A *t*-test was used to analyse the data separately for each depth.

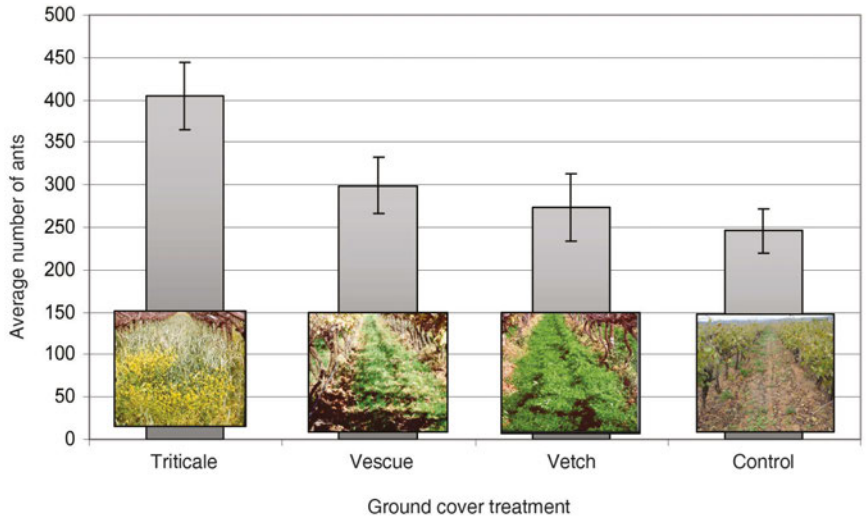

FIG 1: Mean number of pugnacious ants (± standard error bars for four ground cover treatments established in a vineyard in Bonnievale during two years. Numbers with the same letter do not differ significantly (ANOVA, LSD where $P \leq 0.05$).

Cover crops grew well except for dwarf fescue, which was dominated by weeds throughout the year. Control plots were largely free of weeds during summer, although weeds did grow towards the end of winter. Results showed that triticale consistently caused a significant *increase* in ant activity on the ground during both years (Fig. 1), although this did not lead to a significantly higher ant nor mealybug infestation in the vines (Fig. 2). It is possible that the ants were using the seeds of triticale plants as an additional food source. Furthermore, none of the cover crops had any effect on ant nest entrance density, compared to the control, despite the fact that cover crops influenced soil temperatures and moisture significantly. Maximum and minimum soil tempera-

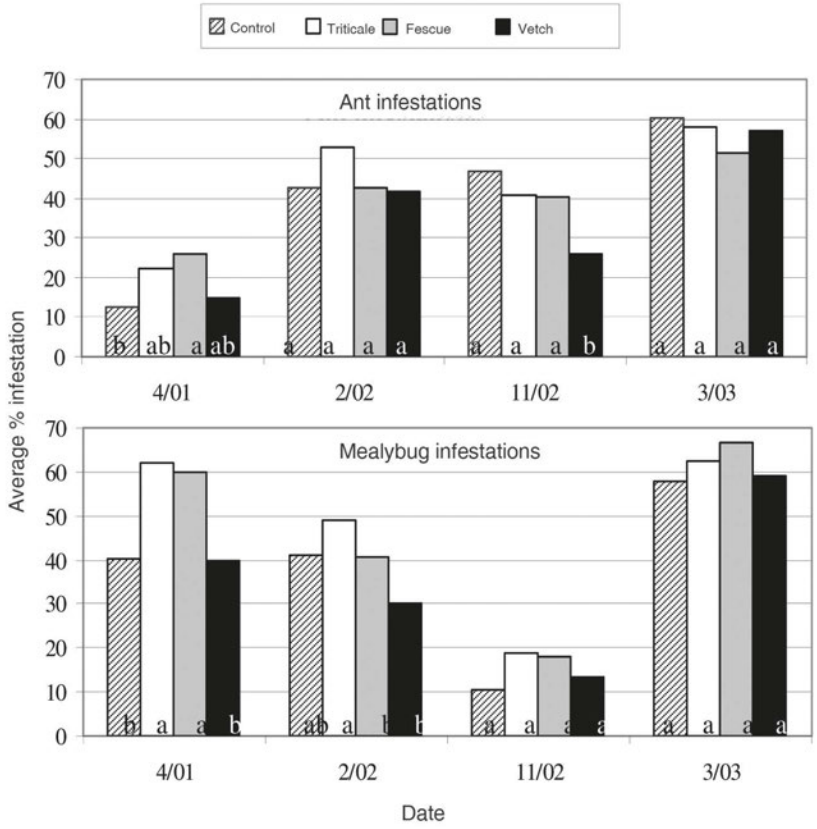

FIG 2: Average percentage pugnacious ant and mealybug infestation in vines, as monitored on four sampling dates, in a vineyard in Bonnievale where four ground cover treatments were compared. April 2001 represents the pre-treatment sampling date. Letters that differ on each column indicate a significant difference ($P \leq 0.05$), analysed for each date separately (ANOVA, LSD) (Reproduced from Addison & Samways, 2006, with kind permission of Springer Science and Business Media).

tures were significantly higher in the control plot than in the cover crop plots at two soil depths: 10 and 30 cm. The highest reduction in soil temperature was 3°C, while a maximum difference of 5,21% soil moisture was found between the control and the fescue, with fescue having the higher soil moisture. The reduction in soil temperature and the increase in soil moisture arising from the use of these cover crops, was, therefore, not enough to affect ant infestations, and the main driver regulating ant abundance in this study was the food source, which dominated over any possible inhibitions imposed by the cover crops. This insensitivity to vegetation cover was also emphasised in Australia, where ants were found to be poor indicators for monitoring grassland condition (New, 2000). None of the cover crops caused a significant increase in the number of parasitoids. In the current study, most (although not significantly more) parasitoids were in the control plots (Fig. 3). This may indicate that a more diverse planting could be of high value to natural enemies in vineyards, in that they provide a greater variety of refugia and nectar sources. Weeds may therefore not be as detrimental as earlier thought, provided that they do not harbour underground mealybug po ways for ants to enter the vine canopy and so hamper the effect of chemical stem barriers.

Conclusins and recommendations

Triticale (where it is used as a viticultural ground cover) must be treated with caution, as it has the potential to increase ant infestations in vineyards already infested with A. custodiens (the common pugnacious ant). This study has clearly indicated that these viticulturally-acceptable cover crops could not be used as a management tool in an integrated mealybug control programme, but that their use did not have any significant negative effects on ant and mealybug infestations in the vine canopy either. Samways (1983) likewise found that habitat modification would not be a suitable method for managing dominant Pheidole spp. in citrus and that trunk barriers are an ecologically more appropriate method of management. The effect that cover crops have on other pest ants in vineyards, e.g. Argentine ant, was not determined in this study, but there are indications from the literature that there is little value in testing cover crops as a management tool for these other ant species.

Acknowledgements

Many thanks to staff of ARC Infruitec-Nietvoorbij, in particular E.C. du Toit and members of the Pest Management Divison for technical assistance, L. Williams for the identification and counting of mealybug natural enemies, V.M. Walton for advice on mealybug and mealybug parasitoid sampling and F. Calitz for assistance with the statistical analyses. Mr F van der Merwe of Bonnievale is thanked for his assistance in the sowing of cover crop seeds and for providing us with a trial site. This project was funded by the Agricultural Research Council (ARC) and Winetech and their contributions are gratefully acknowledged.

References

Addison, P. & Samways, M.J. (2000) A survey of ants (Hymenoptera: Formicidae) that forage in vineyards in the Western Cape Province, South Africa. *African Entomology* 8 (2), 251 – 260.

Addison, P. & Samways, M.J. (2006) Surrogate habitats demonstrate the invasion potential of the African pugnacious ant. *Biodiversity and Conservation* 15: 411 – 428.

Addison, P. (2002) Chemical stem barriers for the control of ants (Hymenoptera: Formicidae) in vineyards. *South African Journal of Enology and Viticulture* 23(1), 1 – 8.

Altieri, M.A. & Schmidt, L.L. (1985) Cover crop manipulation in Northern California orchards and vineyards:

Effects on arthropod communities. *Biological Agriculture and Horticulture* 3, 1 – 24.

Bugg, R.L. & Waddington, C. (1994) Using cover crops to manage arthropod pests of orchards: A review. *Agriculture, Ecosystems and Environment* 50, 11 – 28.

Hofmann, U. (2000) Cover crop management in organic viticulture. *Winepress* 86,12 – 17.

Kriegler, P.J. & Whitehead, V.B. (1962) Notes on the biology and control of *Crematogaster peringueyi* var. *angustior* Arnold on grape vines (Hymenoptera: Formicidae). *Journal of the entomological Society of southern Africa* 25, 287-290.

New, T.R. (2000) How useful are ant assemblages for monitoring habitat disturbance on grasslands in south eastern Australia? *Journal of Insect Conservation* 4, 153- 159.

Pettigrew, S. (1998) Cover crops in Integrated Pest Management. *The Australian Grapegrower and Winemaker*, February, 26 – 27.

Samways, M.J. (1983) Community structure of ants (Hymenoptera: Formicidae) in a series of habitats associated with citrus. *Journal of applied Ecology* 20, 833 – 847.

Tedders, W.L. (1983) Insect management in deciduous orchard ecosystems: Habitat manipulation. *Environmental Management* 7(1), 29 – 34.

Walton, V.M. (2001) Wingerdwitluis: Biologie en beheerstrategie. *Wynboer tegnies* 140, 75 – 78.

Way, M.J. (1953) The relationship between certain ant species with particular reference to biological control of the coreid, *Theraptus* spp. *Bulletin of Entomological Research* 44, 669 – 691.

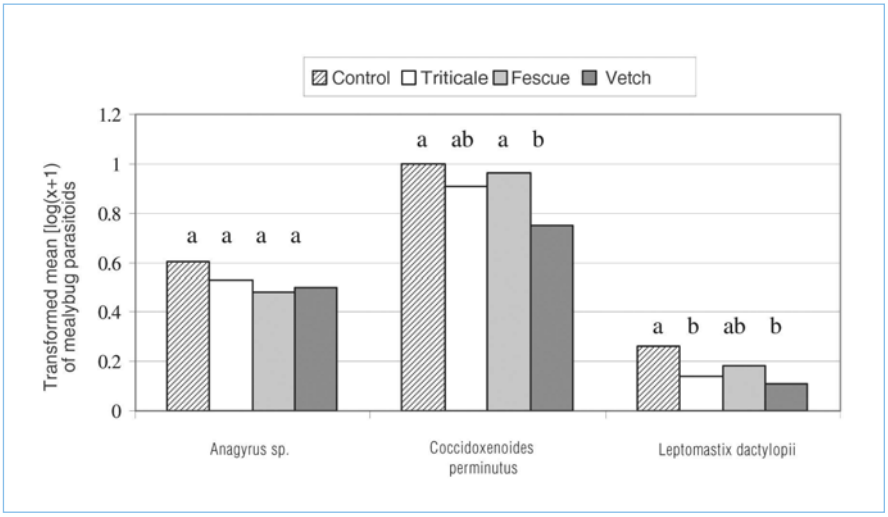

FIG 3: Mean number of mealybug parasitoids caught in sticky yellow Bugtraps™ from July 2001 to March 2003 in a vineyard in Bonnievale where four ground cover treatments where compared.

Unconventional cultivation of grapes for juice, rebate wine and distilling wine

Neels Volschenk

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Key words: viticulture, unconventional, grape juice, rebate wine, distilling wine

Cultivation of grapes for juice, rebate wine and distilling wine are very important facets of the South African wine industry. However, successful establishment of commercial vineyards requires large capital input. This, together with the high annual production costs, makes profitable production of grapes for juice, rebate wine and distilling wine almost impossible, even in areas such as the Lower Orange River Region which may be suitable for mass production. The high costs make it almost impossible for new producers and especially potential producers from previously disadvantaged communities, to enter this segment of the viticultural and wine industry. To address this, a project to investigate alternative cultivation methods with lower establishment and production costs of vineyards for the production of grape juice, rebate wine and distilling wine was initiated on the Eiland Experiment Farm in Upington in 2004. This project is funded by Winetech and the Agricultural Research Council.

– **Establishment of vineyards:**
  The cost of grafted plant material amounts to approximately 25% of the establishment costs of traditional vineyards for the production of grapes for juice, rebate wine and distilling wine in the Lower Orange River Region. To reduce the cost of plant material, Colombar cuttings (approximately 35 cm in length) were collected during pruning from a healthy vineyard with moderately vigorous growth. Most of the cuttings were stored in a cold room after being treated with fungicide. As many producers do not have cold room facilities, some of the cuttings were buried in the ground. This practice is common among producers in the region to store plant material from pruning until the time of planting. The method appears to be equally successful as storing cuttings in a cold room, but it is extremely important that the cuttings do not dry out.

  The cuttings were planted in a sandy, silt soil that was ripped 60cm deep at the end of August 2004. A planting density of 15cm between cuttings in the row (alternative or more cuttings will be removed at a later stage) and one metre between rows was used. Vines were trellised onto a 60cm (from the soil surface) Three Wire Hedge trellising system with two moveable foliage wires. To determine the highest survival percentage and the best growth of cuttings, various establishment techniques, such as the use of rooting agents, cuttings with a piece of two year old wood, and cuttings (80cm in length) that may be tied to the cordon wire at the time of planting, were investigated. Cuttings were first planted in a nursery and the rooted vines were then planted in the vineyard the following year. Cuttings were also planted in combination with grafted vines. The success of the establishment techniques and the growth of the vines are currently being evaluated. Furthermore, a cost analysis is being done for labour input and material.

FIG.1 A Colombar vineyard in which various unconventional viticultural practices were applied.

FIG.2 Dense cover crop plantings to reduce frost damage in spring.

– **Practices to ensure a crop in the first and second years:**
The grapevine is a long term crop and production actually starts three years after establishment only. To address the cash flow problem, several chemical products were applied to Colombar vines in the first and second year after planting to prevent flower clusters from being aborted. The vines are currently being evaluated to determine whether it is indeed possible to obtain a moderate crop in this period.

– **Reduction of frost damage:**
Since soil preparation and irrigation may be done at a lower cost on the low lying, fertile soils in the region, these vineyards are commonly used for the production of grapes for juice, rebate wine and distilling wine. In these areas spring frost commonly occurs. The risk of frost damage is increased in this experiment, given the lower type of trellising system used for the vineyards. Three methods to combat frost damage are being investigated, namely: 1) Selection of cultivars and time of pruning. Six cultivars (Chenin blanc, Palomino, Chenel, Cereza, Viura and Villard blanc) will be pruned at two week intervals from the middle of July to middle October to determine whether it is possible to restrict or prevent frost damage through the timing of pruning and cultivar selection, 2) A protective environment around the vines. Various cover crops are being evaluated to determine the extent to which a protective environment may be formed around the vines to reduce frost damage, and 3) Height of the trellising system. Vines are trellised to different heights (in combination with the different cover crops). For all these methods, frost damage is being evaluated and yield as well as grape composition determined.

FIG.3 Alternative methods for weed control are evaluated in an unconventional high density vineyard.

– **Successful weed control:**
The climate of the region and the high density plantings also create favourable conditions for the growth of weeds and weed control may be difficult. Chemical, mechanical and labour intensive methods (e.g. hoeing), as well as combinations thereof, are being investigated to determine the most practically achievable and economically viable methods for successful weed control.

Results will be released as the investigation progresses.
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Nematodes in vine nurseries – Practical guidelines for the short- and longterm control of nematodes

Compiled by Sheila Storey, Nemlab, on behalf of the Deciduous Fruit Industry

Sheila Storey

Introduction

Nematodes are microsopic worm-like organisms that attack the roots of plants, which if damaged, result in a reduced uptake of nutrients and water.

Vines are attacked by various nematodes, of which the root-knot nematode is the most important. Due to the large-scale use of root-knot nematode resistant rootstocks, the characteristic galls of root-knot nematode are absent. The damage caused by other nematodes is not detectable, both above and below ground. Dagger and ring nematodes are becoming an increasing problem in vines, and control of the latter is problematic.

There are several reasons for the increase in nematode problems over the last number of years. The first reason is the greater awareness of nematode damage. A second reason is the increasing pressure to re-use soils. Certain practices which are carried out give rise to these problems. The fact that establishment takes place on the same soils is the main reason. Associated herewith is the fact that few nurseries consider fumigating the soil, or realise how important it sometimes is.

Different nematodes attack different fruit types (see Table 1).

Nematodes are divided into two groups, depending on their feeding habits, viz. endo- and ectoparasites (Table II).

Infestation sources

There are three possible infestation sources, viz. water, plant material and soil.

Water

Water originating from fast-flowing rivers with significant agricultural activity (particularly vegetable production) can act as a nematode infestation source. Such water is however a minor source of infestation in comparison to the other two sources. The percentage of nematodes that originate from water is minimal. The build-up of nematodes in the soil is thus slow. In the case of nurseries where establishment often takes place on the same soil, the build-up can take place more rapidly.

Plant material

Only rooted plant material can be a possible source of infestation. Such infestation is particularly true of the migrating endoparasite, root-lesion nematode and the sedentary endoparasite, root-knot nematode. Both nematode types live in the roots. It has also been found that ring and dagger nematodes, with their long stylets, are inclined to cling onto roots and can thus be transported together with plant roots.

The current certification scheme requires that plant material must be visibly free of nematode infestation. The scheme does not require a compulsory test for nematodes. The test for Xiphinema index, the carrier of grapevine fanleaf virus, is very specific and does not include the other nematodes. Symptoms of only one nematode, i.e. the root-knot nematode, are visible. No provision is therefore made for the other nematodes within the grapevine certification scheme, not even for low populations of root-knot nematode where the symptoms are not yet visible.

Soil

The soil is the most important infestation source. Infestation in the soil is

Table 1: The host-nematode relationship of the most important nematodes on fruit.

	Peaches	Plums	Apricots	Apples	Pears	Vines
Root-lesion nematode*	xx	xx?	x	xx	x	x
Dagger nematode	xx	xx	x	xxx	xx	xxx
Spiral nematode				x	x	
Stubby-root nematode	x			xx	xx	x
Pin nematode			x	x		
Root-know nematode*(**)	xxx	xxx	x?			xxx
Ring nematode	xxx	xxx	xxx			xxx

xxx Very important, can cause severe damage, occurs commonly
xx Important, can sometimes cause severe damage when the counts are high, occurs commonly
x Seldom causes a problem, little knowledge available regarding the extent of damage caused
* Endoparasites
** Except for root-knot nematode-resistant rootstocks
*** Ring and dagger nematodes can cling onto roots with their long stylets
? Insufficient evidence to establish host status

Table 2: Endo- and extoparasitic nematodes on vines

Endoparasites (feed within the root)	**Ectoparasites** (feed outside on the root)
Root-knot nematode	Ring nematode
Root-lesion nematode	Dagger nematode
Citrus nematode	Stubby-root nematode
	Spiral nematode
	Pin nematode
	Sheath nematode

determined by previous crops, cover crops, weeds or natural vegetation (fynbos) that were present in the soil. Should any of these plants have been a host for the range of nematodes that occur on vines, then the population will increase very quickly in the presence of vines and subsequently cause damage. The new plant material can thus be infected and this infestation is subsequently carried over to the producer.

Monoculture remains a risky practice, and will allow the various nematodes to increase rapidly. The populations later reach a level which is impossible to manage or control, and then fumigation is the only control option. The lack of knowledge of the host status of the previous crop often leads to problems.

Monitoring and control
Prevention is better than control!
Water

Water cannot be treated chemically, it can however be filtered. Any filter, including sandfilters, will give a measure of control. Filters with 5 æm openings are required to totally exclude nematodes from water, but this is impractical in the orchard situation. In the nursery, where water possibly holds a large risk, filters should seriously be considered.

Infestation from rivers can also be drastically reduced by pumping water into dams. The water should preferably stand for 48 hours to give the nematodes time to settle, and then water must be drawn from the surface.

The monitoring of water is impractical and is not recommended.

Plant material

As mentioned previously, only rooted material is a source of infestation. Should rooted material be brought in from outside, it is of critical importance that it is free of nematodes.

The use of a warm water treatment to remove nematodes from plant material is very effective. The plant material is placed in warm water at 50 øC for 15 minutes. This method has been proved and is 100% effective against root-knot nematode. The method is probably also effective against most other nematodes but must still be tested to establish its effectiveness.

Chemical treatment of plant material (root dip) can be problematic and is less effective than the warm water treatment.

There are certain vine rootstocks which provide varying degrees of resistance towards root-knot nematodes (Table III). The plants are however still sensitive to other nematodes that attack them. In the literature there are references to possible sensitivity of certain rootstocks to some of the other nematodes.

Soil
Prior to establishment

It is of critical importance to limit the nematodes in the soil to a minimum before new plantings are established.

- Identify at least one (or more) year(s) in advance (the summer before planting) on which soils new plantings are going to be established. It is particularly old stone fruit and vine soils that cause problems because the same range of nematodes attack these crops (Table 1). Other crops that hold

Table 3: Nematode resistance on certain vine rootstocks.

	Root-knot nematode M incognita	**Ring nematode** M xenoplax	**Dagger nematode** X americanum	**Root-lesion nematode** P vulnus	**Citrus nematode** T semipenetrans
Ramsey	R			R	R
SO4	R				
Dog Ridge	R	S	S	MR	MR
Freedom	R	S	S	MR	S
Harmony	R	S	S	S	S
Paulsen 775	R				
Richter 99	MR	S	S	S	MR
101-14 Mgt	MR				
143 B Mgt	MR				
Paulsen 1103	MR				
Richter 110	MS				
US 8-7	MS				
Paulsen 1447	MS				
Metallica	S				
140 Ruggeri	S				
Jacquez	S				

Scale: R = resistant; MR = mildly resistant; MS = midly susceptable; S = susteptable

possible risks include most vegetables, cucurbits, most weeds, Port Jackson, Acacia, Black Wattle and rye. Except for rye, most of these plants are excellent hosts for root-knot nematodes. Rye and onions are good hosts for root-lesion nematodes.

- Establish the risk of the soil in relation to nematode infestation by taking both soil and root samples. The samples should be taken while a crop is still present, i.e. before trees, vines, or other previous crops are removed from the soil. When the host plants are removed, the nematodes revert to an egg stage, which then makes it impossible to determine populations at a commercial level.
- Remove as many of the old roots of the previous crop as possible. It is particularly the endoparasitic root-lesion and root-knot nematodes which find shelter within the roots.
- The result of the nematode analysis and the time period before the next planting determine what control measures should be applied. Non-chemical measures include a rest/fallow period or the establishment of non- or weak hosts. Other possibilities include solarisation, biofumigation or the use of fumigants.

A fallow period can be considered but it is very important that all weeds and volunteer plants are kept to a minimum. The longer the fallow period for the soil, the more effective the rest period will be for nematode control. It is preferable to rather establish a weak host such as oats than leaving the soil fallow. In the absense of a host, eggs survive for long periods in the soil, and hatch later in the presence of a host. In the case of a weak host the eggs hatch but the nematode cannot complete its life cycle. It is important to again determine the nematode infestation just before the cover crop dies or is ploughed in.

The establishment of non-hosts (particularly for root-knot nematode) such as Tagetes and Crotalaria spp for a period of at least one year, but preferably longer (3 years), should be considered. The long-term establishment (3 years) of Eragrostis spp as a non-host is also a good control measure. It is again important to determine the nematode infestation just before the cover crop dies or is ploughed in.

The establishment of weak hosts in a rotation system can be considered. Crops that are considered weak hosts include oats, triticale and wheat. Rye must be avoided where root-lesion nematode occurs. The effectiveness of the rotation system in terms of nematode control will depend upon the infestation at the beginning of the rotation as well as the time period of the rotation. A period of at least three years is required if the infestation is initially relatively high. Much research still needs to be done to determine the extent of susceptibility of these crops to various nematodes. This is one of the large gaps in our knowledge base. It is important to conduct an analysis of the nematode infestation again just before the crop dies or is ploughed in.

If the population is exceptionally high, and no fallow period is planned, it is sometimes essential to fumigate the soil before the new vines are established. The result of the nematode analysis will give an indication if fumigation is required or not. Some producers believe that chemical treatment after establishment gives the same results as fumigation. This is however not true.

Fumigation can only be carried out prior to establishment. The following fumigants can be considered: methyl bromide; 1,3-D (Telone II); ethylene dibromide (EDB); furfural (Protect) and metham sodium (Herbifume). Each of these fumigants has very specific requirements to guarantee successful treatment. The requirements include, amongst others, temperature, soil type, moisture, organic material content, etc. Establish thus timeously what the requirements of each product are. The requirements are available from Nemlab or the agricultural chemical companies.

Solarisation is a method to control soil-borne organisms and pathogens through the use of raised soil temperatures. The temperature is increased by placing a thin, transparent poly-ethylene plastic over a moist soil surface. Solarisation reduces the nematode population drastically, but will not totally eradicate it.

Biofumigation or biological fumigation is a technique that uses certain plants' own protection functions to control a range of organisms and pathogens, including fungi, bacteria, nematodes, insects and certain weeds. The plants produce special volatile compounds, of which glucosinolates are the most important. Plant types particularly suitable for biofumigation include the family Brassicaceae (cabbage, cauliflower, broccoli, kale, canola and mustard), and the family Moringaceae (horseradish and certain types of radishes). The plants are harvested immature, chopped fine, and worked into the soil. The land then lies fallow for 10 - 14 days before the next crop is planted.

After establishment

It is extremely important that populations are limited to the minimum during this stage. Roots that are damaged in this young stage do not recover easily and will never reach their full potential. The last analysis which was conducted on the site will indicate if chemical treatment after establishment must take place or not.

- **Nursery vines**
  Should the result of the nematode analysis recommend chemical treatment after establishment, then the first treatment can be applied when the white roots are 8 - 10 cm long.
- **During the season**
  Since most nematodes only hatch in the presence of root exudates, it takes approximately six weeks from establishment for the soil to reach an equilibrium. Sampling should thus commence at this stage. Take soil and root samples throughout the growing season. Populations are highest in the summer months and decline as the soil becomes colder. Recommendations based on the results are adjusted according to the time of sampling.
  The results will indicate whether a

treatment is necessary or not. Thereafter, sites can be monitored on a regular basis (ñ every 2 months) and the necessary treatments applied according to the results. Regular monitoring should take place where the infestation is high. Establish the last nematode status from February to March in order that treatments can be carried out timeously.

- **Vines standing over to following season**
  Sampling should begin in the early spring. Take soil and root samples throughout the growing season. Populations are highest in the summer months and decline as the soil becomes colder. Recommendations based on the results are adjusted according to the time of sampling.
  The result of the first sampling will indicate whether a treatment is necessary or not. Thereafter, sites can be monitored on a regular basis (ñ every 2 months) and the necessary treatments applied according to the results. Regular monitoring should take place where the infestation is high. Establish the last nematode status from February to March in the previous season in order that treatments can be carried out timeously.
- **Foundation blocks and mother blocks**
  Always first determine the level of infestation before any action is taken against nematodes. The result of the nematode analysis will indicate the number of treatments. The treatments must commence just before root growth peaks in the spring and autumn. The optimum stage for treatment is within 30 days after harvest, followed by the period just before and after bud-burst. Treatments can be applied throughout the year, but the above-mentioned times give the best results.
  It is important that the periods between treatments are limited to 6 months. The year-on-year treatments are not successful. The ring nematode is more difficult to control and it thus takes longer to achieve a reduction in its numbers. It is unnecessary to eradicate nematodes. Try to reduce nematode numbers to acceptable levels.
  Currently (August 2006) aldicarb (Temik), cadusafos (Rugby) and fenamiphos (Nemacur, Fenamiphos) are registered on vines. The recommended dosages prescribed on the label must be used. It is important to wash the nematicide in with sufficient water (10 - 20 mm). It is also important that the planting row or ridge is free of cover crops or weeds at the time of application. Due to the possibility of accelerated microbial degradation, it is important to alternate the nematicides.
- **Heeling in soils**
  Heeling in soil of both nurseries AND producers should be monitored and, if necessary, appropriate action must be taken. The same rules, as for all soils where planting will take place, apply here.

Choice and use of nematicides

Nematodes are pathogens which must be well managed to reduce the risks. It is incorrect to believe that the problem can be solved by chemical control.

Currently (August 2006) aldicarb (Temik), cadusafos (Rugby) and fenamiphos (Nemacur, Fenamiphos) are registered on vines. The standard dosage for established vines is not sufficient. Due to the close plantings in nurseries the dosage should be determined in conjunction with a chemical company and a nematologist.

The chemicals can possibly be phytotoxic to young vines and should not be applied too early. It is suggested that the first applications take place when the white roots are 8 - 10 cm long. The chemicals must be applied by knapsack sprayers. Application by overhead sprinklers is discouraged.

It is important to wash the nematicide in with sufficient water (10 - 20 mm). Since the soil is already moist, and because irrigation is applied every second day, less water than recommended above is sometimes necessary to wash in the nematicide. It is important that all personnel wear protective clothing, i.e. gloves and gumboots, for one week after the application. It is also important that the soil surface is free of cover crops or weeds at the time of application. Due to the possibility of accelerated microbial degradation, it is important to alternate the nematicides.

The ring nematode is more difficult to control and it thus takes longer to achieve a reduction in its numbers. It is unnecessary to eradicate nematodes. Try to reduce nematode numbers to acceptable levels.

General root health and nursery sanitation

It is advisable to promote root growth with the use of a root stimulant. A mulch on top of the soil or the addition of any organic material will be of great benefit. None of these additions will control high nematode numbers, but will encourage root growth and natural enemies (beneficial soil organisms), thereby reducing damage by nematodes. Nematode numbers will then decline over the long-term.

General nursery hygiene must be maintained at all times. Soil implements that have been used in infected sites must be cleaned before they are moved to new, clean sites. Infected plant material must be removed and burned.

The guidelines as set out above are largely based on experience. Due to the lack of sufficient scientific knowledge, it is not possible to confirm these guidelines with scientific evidence

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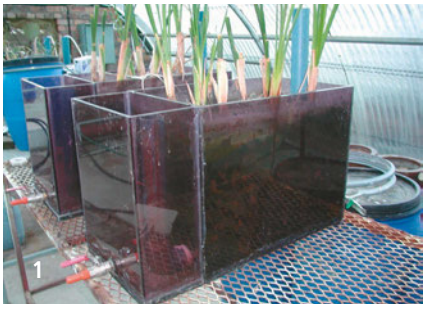
Wetlands consistently clean up organic effluents

Keith du Plessis, ARC Infruitec-Nietvoorbij, Stellenbosch

Keith du Plessis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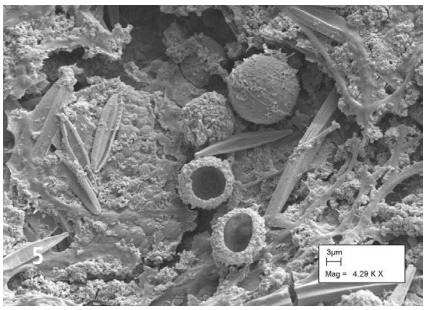

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In view of increasingly stringent wine industry controls on wastewater quality, and of the scarcity of water as a resource, compounded by uncertainties over global warming and its effects, the recent completion of a Ph.D. thesis on the use of artificial wetlands to purify distillery and winery waste water is both welcome and timely.

The study, which was initiated at Distell's Goudini distillery in the Western Cape, set out to explore the possibility of using constructed wetlands to treat distillery wastewater. Initial findings showed that artificially constructed wetlands do, indeed, have the ability to treat distillery wastewater provided that the chemical oxygen demand of the effluent does not exceed 15 000 mg/L, and are able to do so over protracted periods of time provided that the correct substrate materials are used.

These studies revealed that, far from being uniform and reasonably static, microbial communities in artificial wetlands are highly dynamic. Communities varied between zones in the same wetland, between different wetlands, and between communities sampled from the same zone at different times. Notwithstanding this microbiological variability, artificial wetlands were consistently able to remove, or to degrade, the materials that create a demand for oxygen, resulting in decreases in chemical oxygen demand of up to 90%.

Work which is still gaining momentum concerns the identification of species of micro-organism which are exceptionally efficient at breaking down organic effluents. That such organisms exist, is strongly suggested by the results of trials in which wetland microbial communities were augmented with concentrated ferments of microbes derived from the wetlands themselves.

Collectively, results obtained to date indicate that, in terms of their effectiveness in breaking down distillery and, by inference, winery effluents, the microbiological communities in artificial wetlands are remarkably robust. This bodes well for the many branches of agricultural in which organic effluents are generated.

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1. Lab-scale constructed wetlands (50 cm long x 40 cm high x 30 cm wide) made out of perspex. The substrate material is ~2 mm diameter gravel and is planted with Typha sp. plants.
2. Lab-scale constructed wetland that is under stress.
3. Lab-scale set-up. Wastewater are pumped from a settling tank into the wetland via an inlet pipe which extends to the bottom of the tank. From there it is pushed through the tank, which has a 1% slope to the outlet, and into a holding section at the outlet of the system.
4. Healthy lab-scale wetland.
5. Microbial colonisation on a piece of gravel isolated from a constructed wetland.

The Mycorrhizal Fungus – a lifelong partner of the grapevine

André Meyer, ARC Infruitec-Nietvoorbij, Stellenbosch

Key words: mycorrhizae, grapevines, fungus, root, colonisation, soil, hyphae

André Meyer

Introduction

Arbuscular mycorrhizal (AM) fungi are an exceptional group of beneficial fungi. They are present in most soils and are capable of forming associations with the root systems of the great majority of vascular plant species, where they act as bioregulators and protectors, and facilitate the uptake of mineral nutrients (Lovato et al., 1996). This article concerns the relationship between AM fungi and the grapevine, a topic that has received little attention in the popular viticultural press to date.

Fungi have different forms and behaviour patterns. Some digest decaying wood, or organic material in the soil and produce conspicuous fruiting structures. Others, including the arbuscular mycorrhizal (AM) fungi are microscopic and can only be examined properly through a microscope after being stained with special dyes. All AM fungi are soil-borne and are most abundant in that region of the soil which immediately surrounds the roots. This is referred to as the rhizosphere or, sometimes, as the mycorrhizosphere. The AM fungi form networks in the rhizosphere and also extend into the roots. Since AM fungi are unable to grow and reproduce in regions of the soil where host plant roots are absent, they are considered to be obligate biotrophs. Arbuscular mycorrhizal fungi are nevertheless capable of surviving in the bulk soil as dormant spores, germinating if a root moves into their vicinity.

In mycorrhizal relationships, the fungus acts as an extension of the host's root system, greatly facilitating the uptake of slowly diffusing soil nutrients, such as phosphorus (P), as well as water. This uptake is made possible by the very extensive nature of the network of nutrient detecting thread-like filaments of which the fungus is composed. In return, the plant provides the fungus with a congenial environment rich in food materials, notably carbon compounds produced during photosynthesis, which the fungus cannot produce for itself. This is commonly referred to as a bi-directional transfer of nutrients (Smith et al., 1994). The essence of the symbiotic relationship is that both host and fungus benefit.

FIG 1: Mature spores of the AM fungus, *Gigaspora gigantia*.

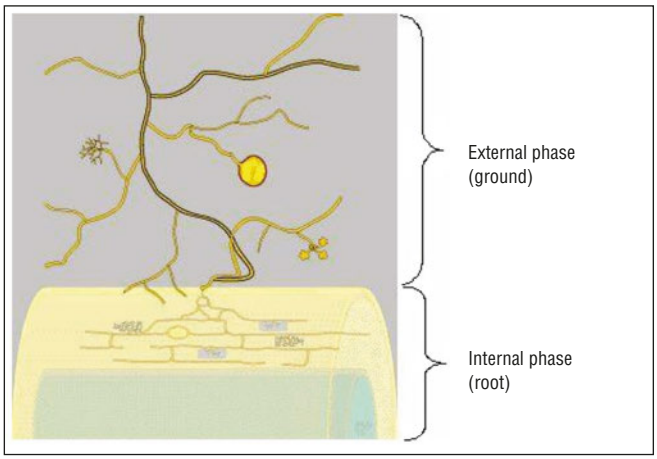

FIG 2: External and internal phases of mycorrhizal root colonisation (adapted from Brundrett, 2001).

Grapevines have much coarser root systems than annual crops and so are more likely to benefit from a mutualistic relationship with AM fungi (Baylis, 1970; Crush, 1973; Linderman, 1988). It is therefore not surprising that AM are commonly encountered when field-grown vine roots are studied under the microscope. In fact, vine roots, in common with roots in general, exude chemical compounds that increase host susceptibility to colonisation by AM fungi. Production of such exudates varies according to the time of the season and to the host's growth stage. Consequently, grapevines vary in terms of their ability to attract specific AM fungal species with season and growth stage. Single plants may host a number of AM fungal species at the same time.

Process of establishment

Since AM fungi live partially within the roots of grapevines, they must first establish themselves within the root tissue before they can render any benefit to the host. There are two main phases in the establishment of a functional symbiosis between AM fungi and grapevines, namely, an external phase (in the soil) and an internal phase (inside the grapevine's root tissue) (Fig. 2).

– **External phase:** In the external phase, the fungus pro-

duces thread-like filaments, called hyphae. Hyphae have various morphologies and functions. Some are fertile, others absorptive, and some are infective. Collectively, the vast network of hyphae in the soil around the root is known as the mycelium. Absorptive hyphae are extremely thin, in some cases only one fifth of the diameter of a root hair. This characteristic enables absorptive hyphae to penetrate soil pores that are inaccessible to even the finest roots. The overall volume of soil that is exploited for nutrients and water by a mycorrhizal root system is therefore considerably greater than that which is accessible to a non-mycorrhizal root system. Fertile hyphae bear spores which become distributed through the body of the soil. The spores, which are usually spherical, thick-walled, resting structures, germinate under suitable conditions to produce the thick infective hyphae which are responsible for root colonisation.

A sequence of recognition events leads up to the morphological and physiological integration of the partners in the symbiosis (Nagahashi & Douds, 1997). Infective hyphae are apparently induced to grow towards young, actively growing grapevine roots by a kind of sensing mechanism. These infective hyphae may originate from older roots that are already infected, from spores that are attached to infected roots, or from isolated, detached spores in the soil. As a rule, hyphae only colonise fine roots, not those that have become woody.

As soon as contact is made with the root epidermal layer the hypha grows along the surface of the root for a short distance before enlarging to form an organ known as an appressorium between adjacent epidermal cells. Numerous such infection points usually form on the surface of a single root.

– **Internal phase:** From the appressorium, the hypha penetrates the root surface and spreads through the root tissue. Penetration of the root tissue marks the beginning of the internal phase. How it does so depends on the anatomy of the root, and on the fungal species involved. In the case of Arum-type spreading the hypha enters the root between epidermal cells (the entry point) and spreads by growing along the air channels between the cells (the intercellular spaces). In contrast, in Paris-type spreading, the hypha directly penetrates the outer (epidermal) cell and spreads through the underlying cortex by passing through, rather than around, the cells. This intracellularly type of spreading pattern results in the characteristic looped arrangement of hyphae shown in Fig. 3).

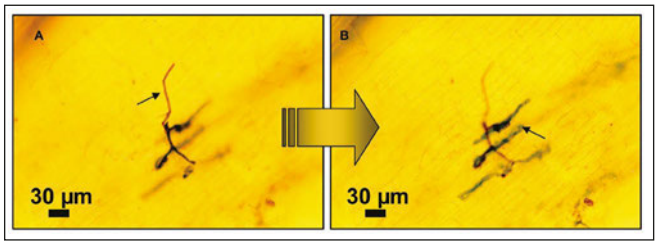

FIG 3: Inwards progression of fungal penetration in grapevine root tissue: (A) Single infective hypha having spit in three, each of which having formed an appressorium and an infection point in the epidermal layer. (B) Characteristic looped arrangements.

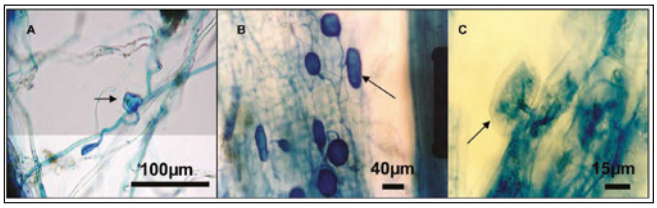

FIG 4: AM structures formed during root colonisation: (A) Accessory body, (B) Vesicle and (C) Arbuscule. Arrows point to structures.

As spreading progresses, various structures are formed by the AM fungus. These include vesicles, arbuscules, and, in exceptional cases, spores (Fig. 4). Vesicles are balloon-like structures and are mainly responsible for the storage of such plant metabolites as lipids. Vesicles may form within, or between, the host root cells. A major sub-group of AM fungi however, does not form vesicles inside root tissue. Instead, they form vesicle-like structures outside the root in the soil. These external vesicles form clustered swellings on external soil hyphae and are often ornamented with spines or knobs. They are believed to have a similar function to that of the normal vesicles, except that they form part of the external phase. Arbuscular mycorrhizal fungi also form tree-shaped or bush-like structures. These are specialised organs which play a highly active role in the exchange of materials between the fungus and the host cell. These exchange structures (arbuscules) develop inside root cortical cells and link with the external absorptive hyphae through which soil nutrients are transferred to the host.

Beneficial effects

– **Protection against disease:** Young vines are highly susceptible to infection by pathogenic fungi. The AM fungus competes with pathogenic fungi for infection sites on the grapevine root surface. Since the AM fungi are highly competitive, pathogens are largely excluded by this process (Vigo et al., 2000). Although fungal pathogens compete with AM fungi for carbon and other nutrient sources (Graham, 2001), the AM fungi usually outperform the pathogen. By these means, and without any form of outside assistance, AM fungi are capable of being highly effective biological control agents (Vigo et al., 2000). In cases where AM fungi do not provide complete control over a specific disease, they nevertheless contribute to the defence of the host by engaging in a combined effort with other biological control agents (Nemec, 1997), sometimes including such other symbionts as root nodulating bacteria (Dar et al., 1997). Arbuscular mycorrhizal fungi may also produce chemical compounds with antimicrobial properties (toxins) that prevent other, unwanted, fungi from entering the roots, thereby ensuring their own establishment within the host.
– **Improving soil structure and aggregate stability:** The vast network of hyphae produced by the AM fungus, contributes to the structure and stability of agricultural soils (Bearden & Peterson, 2000). Glomalin, an insoluble glycoprotein produced by AM fungal hyphae, is particularly important for the aggregation and stabilization of

soils (Wright et al., 1999) since it has the ability to bind soil particles together. The integrity of the delicate soil hyphal network is, however, extremely sensitive to any form of disruption, of which the most violent is mechanical cultivation, such as ploughing. Disruption or detachment due to soil disturbances is particularly severe in the topsoil where cultivation-induced reductions in spore density may be expected (Kabir et al., 1998). Thus, if the abundance of AM fungi is to be maintained, damaging cultivation management practices must be avoided. Where possible, zero tillage should be encouraged, rather than conventional tillage practices.

- **Applying organic amendments to soil:** By improving the soil organic content, the number of spores may be considerably increased (Cuenca et al., 1998). Application of organic amendments, such as compost and manure, has been shown to positively affect spore numbers in soil (Douds et al., 1997). Also, AM fungi may have direct access to organic P through the production of specific P-releasing enzymes, the so-called extracellular phosphatases, by the hyphae (Koide & Kabir, 2000).
- **Sowing cover crops in vineyards:** Cover crops play host to a wide range of AM fungi. Once sown, they set in motion a vast underground process of hyphal growth and spore production (Fig. 5). Under these circumstances, pieces of infected root, spores and hyphae that have survived in the soil from the preceding season all act as propagules or sources of inoculum for the cover crop. In addition, because the root systems of the cover crop and grapevine become intertwined, fresh supplies of inoculum are passed on to grapevine.

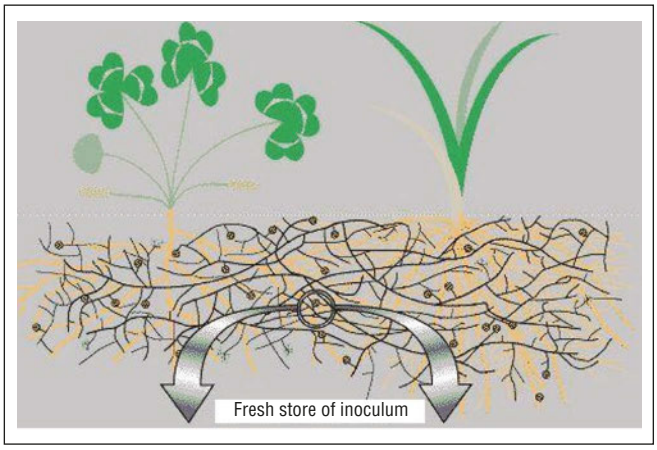

FIG 5: Schematic representation that shows how cover crops promote below-ground hyphal growth and subsequent spore production (adapted from Brundrett, 2001).

Conclusions

Arbuscular mycorrhizal fungi are wholly natural components of the micro ecology of vineyard soils. They have the ability to improve nutrition and root resistance to attack by pathogens, and also contribute positively to soil structure and stability. The beneficial effects of AM fungi in vineyards are nevertheless largely unappreciated at present. Recognition of their importance as components of healthy soils, and the implementation of practices that favour their propagation, are important aspects of vineyard management.

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Literature cited

Baylis, G.T.S., 1970. Root hairs and phycomycetous mycorrhizas in Phosphorous deficient soils. Plant Soil 33, 713-716.

Bearden, B.N. & Peterson, L., 2000. Influence of arbuscular mycorrhizal fungi on soil structure and aggregate stability of a vertisol. Plant Soil 218, 173-183.

Brundrett, M., 2000 "Vesicular-Arbuscular Mycorrhizas" Section 3. Arbuscular Mycorrhizas. 21 June. http://www.ffp.csiro.au/research/mycorrhiza/vam.html, 28 November 2001.

Crush, J.R., 1973. The effect of Rhizophagus tenius mycorrhizas on ryegrass, cocksfoot and sweet vernal. New Pathol. 72, 965-973.

Cuenca, G., De Andrade, Z. & Escalante, G., 1998. Diversity of Glomalean spores from natural, disturbed and revegetated communities growing on nutrient-poor tropical soils. Soil Biol. Biochem. 30, 711-719.

Dar, G.H., Zargar, M.Y. & Beigh, G.M., 1997. Biocontrol of Fusarium Root Rot in the common bean (Phaseolus vulgaris L.) by using symbiotic Glomus mosseae and Rhizobium leguminosarum. Micro. Ecol. 34, 74-80.

Douds, D.D., Galvez, L., Franke-Snyder, M., Reider, C. & Drinkwater, L.E., 1997. Effect of compost addition and crop rotation point upon VAM fungi. Agric. Ecosyst. Environ. 65, 257-266.

Graham, J.H., 2001. What do pathogens see in mycorrhizas? New Phytol. 149, 357-359.

Kabir, Z., O'Halloran, I.P., Widden, P. & Hamel, C., 1998. Vertical distribution of arbuscular mycorrhizal fungi under corn (Zea mays L.) in no-tillage and conventional tillage systems. Mycorrhiza 8, 53-55.

Koide, R.T. & Kabir, Z., 2000. Extraradical hyphae of the mycorrhizal fungus Glomus intraradices can hydrolyse organic phosphate. New Phytol. 148, 511-517.

Linderman, R.G., 1988. Mycorrhizal interactions with rhizosphere microflora: The mycorrhizosphere effect. Phytopathol. 78, 366-371.

Lovato, P.E., Gianinazzi-pearson, V., Trouvelot, A. & Gianinazzi, S., 1996. The state of art of mycorrhizas and micropropagation. Advances in Horticultural Science 10: 46-52.

Nagahashi, G. & Douds Jr, D.D., 1997. Appressorium formation by AM fungi on isolated cell walls of carrot roots. New Phytol. 136, 299-304.

Nemec, S., 1997. Longevity of microbial biocontrol agents in a planting mix amended with Glomus intraradices. Biocontrol Sci. Technol. 7, 183-192.

Smith, S.E., Gianinazzi-Pearson, V., Koide, R. & Cairney, J.W.G., 1994. Nutrient transport in mycorrhizas: structure, physiology and consequences for efficiency of the symbiosis. Plant Soil 159, 103-113.

Vigo, C., Norman, J.R. & Hooker, J.E., 2000. Biocontrol of the pathogen Phytophthora parasitica by arbuscular mycorrhizal fungi is a consequence of effects on infection loci. Plant Pathol. 49, 509-514.

Wright, S.F., Starr, J.L. & Paltineanu, I.C., 1999. Changes in aggregate stability and concentration of glomalin during tillage management transition. Soil Sci. Soc. Am. J. 63, 1825-1829.

The effect of irrigation on growth, yield, wine quality and evapotranspiration of Colombar in the Lower Orange River Region

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Key words: Grape vine, irrigation, shoot growth, yield, wine quality, evapo-transpiration, water use efficiency.

Introduction

The motivation for effective irrigation of wine grapes is to maintain optimal yield while maintaining wine quality. As a result of limited water resources, producers should also attempt to achieve the highest possible yield with the least water without sacrificing wine quality. To be able to follow the correct irrigation strategy, the water requirements of grape vines should be known. The water requirement may differ from region to region, however, as a result of differences in soil type, climate, cultivation practices as well as the specific end product (Myburgh, 1998). Although the cultivation of wine grapes is an established industry in the Lower Orange River region, the water consumption, in other words evapotranspiration (ET), of wine grapes in this area, with its singular soils and climate, has not yet been determined. Previously the determination of ET and crop coefficients of wine grapes was limited to the Western Cape (Van Zyl, 1984a; Van Zyl & Fourie, 1988; Myburgh *et al.*, 1996). Furthermore the published crop coefficients are only applicable to the American Class-A evaporation pans. It is therefore not applicable to the reference evapotranspiration that is nowadays calculated from weather data. The effect of different irrigation strategies on wine quality has not previously been determined in the Lower Orange River region.

The purpose of the project was to determine how different irrigation cycle lengths will influence the growth, yield, wine quality and ET of grape vines on alluvial soils in the Lower Orange River region.

Material and methods

The investigation was carried out using Colombar/99R in the Gariep vicinity, situated between Upington and Groblershoop in the Northern Cape. At the start of the field trial the grape vines were eight years old. The grape vines were planted in alluvial soil, representative of the Dundee form (Soil Classification Work Group, 1991). The soil was deep ploughed before establishment, using a wheel tractor. The plant spacing was 3.3m by 1.8m. The root system was well developed in the 600mm deep silt rich topsoil. There were only a few roots in the sandy subsoil. This situation is common in the alluvial soils of the Lower Orange River region. The grape vines were developed on a T-trellis (Zeeman, 1981) and pruned to short bearers.

Four treatments were applied by irrigating once a week, every 14 days, 21 days and 28 days, respectively. Each irrigation treatment was replicated five times in a randomised block design. On each experimental plot, the row of six experiment grape vines was bordered by two grape vines at each end, as well as on both sides by two rows to prevent overlapping of treatment effects. The irrigation treatments were applied over four seasons (1996/97 to 1999/2000) from bud break at the beginning of September to post-harvest in February. The vineyard was not cultivated mechanically during the duration of the field trial. Summer and winter weeds were controlled chemically over the entire surface.

Although the grape vines were planted in alluvial soil, irrigation was applied using micro-sprinklers instead of the more common flood method so that the irrigation quantities could be applied and measured more accurately. The flow rate of the micro-sprinklers (Eintal) was 32L/hour at 100kPa work pressure. The sprinklers were mounted on stakes so that the most even horizontal distribution of water possible could be obtained.

Soil water content was measured weekly using a neutron moisture probe at 30cm, 60cm and 90cm depths. The probe was calibrated against gravimetric soil water content for the specific soil at each depth. Irrigation volumes were monitored using water meters. Initially the irrigation volumes were calculated using crop coefficients that had been determined for Sultanina in alluvial soil near Upington in the early nineties (Myburgh, 2003a). The irrigation quantities were gradually adapted to the different treatments by measuring the soil water content before and after irrigations. The universal water balance equation was used to calculate ET on a weekly basis as described by Myburgh (2003b). The atmospheric conditions and rainfall were measured using an automated weather station that had been erected at the trial. The reference evapotranspiration (ET_o) was calculated from weather data using a modified Penman-Monteith equation (Allen *et al.*, 1998). Crop coefficients were calculated by dividing the total ET for a specific week by the corresponding ET_o.

Vegetative growth was quantified by measuring cane mass at pruning. The leaf area index (LAI), in other words square metre of leaves per square metre of soil surface, was measured at various stages of the growing season. Yield was determined by weighing the total amount of grapes on each trial site and converting this to tons per hectare. The total number of bunches per site were counted to calculate the bunch mass from the total crop mass. The berry mass was determined at harvest. For this purpose five berries from 20 different bunches on each plot were removed by using a pair of scissors. Sugar and acid content as well as the pH of the must were also determined during the harvest according to the standard procedures of the cellar at Nietvoorbij. Grapes from all the replications of each treatment were transported to Nietvoorbij, where experimental wines were vinified on a small scale according to the procedure described by Myburgh (2006a). The fermentation bouquet, acidity and overall wine quality were judged sen-

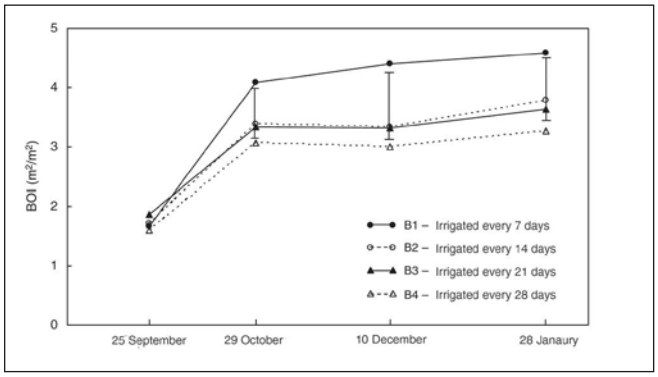

FIG 1: The effect of the length of the irrigation cycle on the leaf surface index of Colombar during the 1997/98 season at Gariep in the Benade-Orange River Region.

sorially on an eight point scale each year in August by a panel of experts.

Results and discussion

Vegetative growth: By the end of September approximately half the vegetative growth had already taken place (Fig. 1). The leaf canopy of all the treatments was almost fully developed by the end of October. At that stage grape vines from the wettest treatment already had more leaves than those of the driest treatment. The wettest treatment (T1) had stronger shoot growth compared to the three drier treatments (Table 1). This was to be expected, seeing that shoot growth of wine grape cultivars, including Colombar, usually reacted readily to the water status in the soil (Van Zyl, 1984b; Myburgh, 2003b). In general shoot growth was stronger compared to the 2.4 t/ha for Sultanina in alluvial soil where irrigation was applied using furrows and drippers (Myburgh, 2006b). Seeing that it is not always possible in practice to apply canopy management in vigorously growing grape vines on the fertile alluvial soil, alternative irrigation strategies may be considered. Research has shown that irrigation may be applied every 14 days in alternative rows to restrict shoot growth of Sultanina in the Lower Orange River valley without sacrificing yield (Myburgh, 2003a). If a strategy such as partial wetting of the root zone may be applied successfully (partial root zone drying = PRD), it could be beneficial where vigorous shoot growth on the alluvial soils may be detrimental to wine quality.

Yield: Berry size was reduced to such an extent in conjunction with an increased irrigation cycle length that berries of T2, T3 and T4 were significantly smaller compared than that of T1 (Table 1). A similar reaction was obtained where Colombar in the Breede River valley was irrigated at different soil water depletion levels (Van Zyl, 1984a). In general berries of all the treatments were smaller, however, compared to the approximately 1.7g/berry of the driest level reported for the Breede River valley study. As a result of the smaller berries the bunch mass of T4 was lower than that of T1. The larger berries and heavier bunches caused the yield of T1 to be significantly higher compared to all the other treatments (Table 1). During the 1998/99 season hail destroyed almost 50% of the crop. Even so the yield of the grape vines that had been irrigated weekly was still higher than those which received the least amount of irrigation.

Sugar, acid and pH of the must: The grapes are usually ready for harvesting during the first week of February. During the 1996/97 season the average yield was approximately 60t/ha. The grapes from the wettest treatment could only be harvested approximately three weeks after the other treatments. During the other seasons the average yields were lower and the tempo of ripening of all four treatments was more comparable so that all the grapes could be harvested on the same day. These results indicate that a combination of high crop loads and wet soil conditions may hamper ripening even in a warm, arid climate. The wetter soil conditions of T1 had no effect on sugar content, but delayed the reduction in acid (Table 2). Previous results showed that the wetter soil conditions are not only able to delay the reduction in acid in Colombar grapes, but that these may also cause sugar to increase more slowly (Van Zyl, 1984b). Despite the warm, dry conditions the acid content of the must was generally fairly high. The respective irrigation treatments did not have an effect on the must pH (Table 2). The must pH of all the treatments was within acceptable levels. Similar results were obtained with Colombar in the Breede River valley (Van Zyl, 1984b).

Wine quality: As a result of incomplete fermentation occurring in all the replications of the four treatments, experimental wines could not be made during the 1999/2000 season. Seeing that all viticultural practices, as well as the irrigation treatments, were applied just like the first three seasons, there is no explanation for the fermentation problem. The experimental wines were generally not of exceptional quality in any of the seasons. This could have been the result of negative effects of the warm, arid climate on the flavour intensity (Marais *et al.*, 1999). The respective irrigation treat-

TABLE 1: Effect of irrigation cycle length on shoot, berry and bunch mass as well as yield of Colombar, as measured over four seasons at Gariep in the Lower Orange River Region.

Treatment	Shoot mass (t/ha)	Berry mass (g/korrel)	Bunch mass (g/tros)	Yield (t/ha)
B1 – Irrigated every 7 days	3.8a*	1.65a	193a	44.0a
B2 – Irrigated every 14 days	3.3b	1.53b	174ab	39.4b
B3 – Irrigated every 21 days	3.2b	1.49b	174ab	38.3b
B4 – Irrigated every 28 days	3.1b	1.43b	158b	36.4b

*** Figures followed by the same letter within a column do not differ significantly (p = 0.05).**

TABLE 2: Effect of irrigation cycle length on sugar, acid and pH in Colombar as measured over four seasons at Gariep in the Lower Orange River region.

Treatment	Sugar (°B)	Acid (g/L)	pH
B1 – Irrigated every 7 days	19.9a*	8.8a	3.29a
B2 – Irrigated every 14 days	20.2a	8.4b	3.27a
B3 – Irrigated every 21 days	20.3a	8.3b	3.25a
B4 – Irrigated every 28 days	20.2a	8.2b	3.25a

*** Figures followed by the same letter within a column do not differ significantly (p = 0.05).**

ments did not have a significant effect on any of the wine quality parameters over the three seasons (Fig. 2). Previous research also showed the wine quality of Colombar to be fairly insensitive to irrigation (Van Zyl, 1984a). In all three seasons there was an obvious trend towards a more prominent fermentation bouquet as well as better overall wine quality in the case of the 28-day irrigation cycle (Fig. 2). It is important to note that the wine quality tended to increase when berry size decreased as a result of drier soil conditions. A similar tendency regarding wine quality and berry size also occurred in the coastal region of the Western Cape in Chenin blanc (Marais *et al.*, 2005) and Sauvignon blanc (Myburgh, 2006a). This suggested that smaller berries as a result of reduced irrigation will not necessarily increase the quality of white wine dramatically. The results also showed that drier soil was only conducive to improved wine quality under a given set of circumstances and that irrigation per se was definitely not an overriding factor with regard to wine quality.

Evapotranspiration and crop coefficients: During the last season the water meters with which the irrigation quantities had been measured, were damaged to such an extent that the ET could not be determined. In general the ET and crop coefficients decreased together with an increase in irrigation cycle length (Table 3). The smaller leaf area of the drier treatments (Fig. 1) probably contributed to the lower ET compared to the 7-day cycle (T1) seeing that less water could be lost through transpiration. Drier soil conditions, which reduce the transpiration tempo of grape vines (Van Zyl, 1984a; Myburgh *et al.*, 1996), could also have contributed to the lower ET of the grape vines that were less regularly irrigated. Furthermore, regular, high evaporation losses from the wet soil in the case of the weekly irrigation (T1) may have increased the ET compared to the longer irrigation cycles (Myburgh, 1998). Research in Australia also showed that the ET of Colombar in drier soil was lower than in wetter soil (Stevens & Harvey, 1996). The ET difference between 21- and 28-day irrigation cycles (T3 and T4) was so small that it may be disregarded, however, and may therefore be considered the same for all practical intents and purposes. Although an accurate calibration was obtained with regard to the gravimetric soil water content, the neutron moisture probe was probably not sensitive enough to quantify the differences between T3 and T4.

The total annual ET of T2 and T3/ T4 was respectively approximately 14% and 25% less than that of T1 (Table 3). The total ET of the respective treatments was also considerably less than the annual allocation of 15 000m^3 water quota per hectare in this particular area. The ET of the two driest treatments was comparable to the approximately 7 000m^3 required to irrigate Sultanina in alluvial soil near Upington using furrows (Myburgh, 2003a; Myburgh 2006b), but was more than the 6000 m^3 required for the irrigation of Colombar under cooler conditions in the Breede River valley (Van Zyl, 1984a). It should be borne in mind, however, that irrigation is more efficiently applied using micro-sprinklers than full surface flood irrigation. If vineyards in the Lower Orange River region are flooded weekly from September to February, the ET will probably exceed the allocated quota. If one assumes the efficiency of the micro-sprinklers to be 80%, the relationship between the amount of grapes produced and the amount of water applied, is 3.4kg/m^3, 3.6kg/m^3 and 3.9kg/m^3 for T1, T2 and T3/ T4, respectively. The water use efficiency in terms of the unit mass grapes per unit volume water was therefore lower than the 5.2kg/m^3 when Sultanina in alluvial soil near Upington was irrigated using furrows or drip irrigation (Myburgh, 2006c). The foregoing also illustrates the extent to which water savings are possible, while retaining yield, if vineyards are not irrigated over the full surface.

Conclusions

The ET decreased with an increase in the irrigation cycle length. Where irrigation was applied every 21 or 28 days, there was no difference in ET for all practical intents and purposes. Shoot growth, berry size and yield also decreased with an increase in irrigation cycle length. There was a tendency towards improved wine quality when irrigation was applied less regularly. If improved wine quality is the primary goal, and producers are rewarded accordingly, it

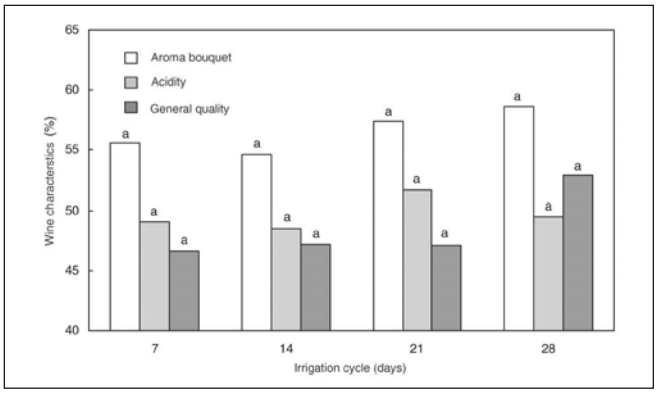

FIG 2: The effect of the length of the irrigation cycle on wine quality of Colombar as measured between the 1996/97 and 1998/99 seasons at Gariep in the Benade-Orange River Region. Columns followed by the same letter do not differ significantly. (p = 0.05).

TABLE 3: Average monthly Penman-Monteith reference evapotranspiration (ET), as well as effect of irrigation cycle length on average daily evapotranspiration (ET) and crop coefficients for each month as determined over three seasons (1996/97 to 1999/2000) at Gariep in the Lower Orange River Region.

Month	ET_o (mm/day)	ET (mm/day) Irrigation cycle (days)			Crop coefficient Irrigation cycle (days)		
		7	14	21/28	7	14	21/28
September	5.3	2.1	1.9	1.7	0.39	0.35	0.31
October	6.7	3.1	2.6	1.9	0.46	0.38	0.28
November	7.9	4.1	3.6	2.6	0.52	0.46	0.33
December	9.3	5.5	4.6	4.2	0.59	0.49	0.45
January	8.7	5.1	3.9	3.2	0.59	0.44	0.37
February	8.6	4.5	3.4	2.7	0.53	0.40	0.32
March	6.8	2.9	2.7	2.7	0.42	0.40	0.40
April	4.8	1.6	1.5	1.5	0.33	0.30	0.30
May-August	3.7	1.2	1.2	1.2	0.32	0.32	0.30
Total ET per annum (mm)		**1022**	**881**	**769**			

may be financially rewarding to irrigate less. If this is not the case, however, it may be more profitable to maintain higher yields due to wetter soil conditions. The use of an irrigation strategy such as PRD to restrict shoot growth, but not the yield, must be investigated through ongoing research. If it can be applied successfully, a strategy like this may be beneficial where vigorous shoot growth on the fertile alluvial soils may be detrimental to wine quality.

Acknowledgements

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Literature references

Allen, R.G., Pereira, L.S., Raes, D. & Smith, M., 1998. Crop evapotranspiration: Guidelines for computing crop water requirements. Irrig. Drain. Pap. 56, FAO, Rome.

Marais, J., Hunter, J.J. & Haasbroek, P.D., 1999. Effect of microclimate, season and region on Sauvignon blanc grape composition and wine quality. S. Afr. J. Enol. Vitic. 20, 19 - 30.

Marais, J., Van Schalkwyk, D. & October, F., 2005. Effek van korrelgrootte, sonligblootstelling en rypheid op Chenin blanc wynkwaliteit. Wynboer, August 2005, 14 - 15.

Myburgh, P.A., Van Zyl, J.L. & Conradie, W.J., 1996. Effect of soil depth on growth and water consumption of young *Vitis vinifera* L. cv. Pinot noir. S. Afr. J. Enol. Vitic. 18, 53 - 62.

Myburgh, P.A., 1998. Water consumption of South African vineyards: A modelling approach based on the quantified combined effects of selected viticultural, soil and meteorological parameters. PhD thesis, Stellenbosch University, Private Bag X1, Matieland 7602, South Africa.

Myburgh, P.A., 2003a. Possible flood irrigation technologies to reduce water use of Sultanina grape vines in a hot, arid climate. S. Afr. J. Plant Soil 20, 1 - 8.

Myburgh, P.A., 2003b. Responses of *Vitis vinifera* L. cv. Sultanina to level of soil water depletion under semi-arid conditions. S. Afr. J. Enol. Vitic. 24, 16 - 24.

Myburgh, P.A., 2006a. Juice and wine quality response of *Vitis vinifera* L. cvs. Sauvignon blanc and Chenin blanc to timing of irrigation during berry ripening in the Coastal region of South Africa. S. Afr. J. Enol. Vitic. 27, 1 - 7.

Myburgh, P.A., 2006b. 'n Ondersoek na moontlike waterbesparing met ondergrondse besproeiing I – Besproeiinghoeveelhede, benattingpatrone en wortelverspreiding. Wynboer, February 2007, 12 - 16.

Myburgh, P.A., 2006c. 'n Ondersoek na moontlike waterbesparing met ondergrondse besproeiing II – Plantwaterspanning, groei, produksie en gehalte. Wynboer, March 2007, 13 - 16.

Soil Classification Work Group, 1991. Soil classification – A taxonomic system for South Africa. Dept. of Agricultural Development, Private Bag X144, Pretoria 0001, South Africa.

Stevens, R.M. & Harvey, G., 1996. Soil water depletion under large grape vines. Aust. J. Grape Wine Res. 2, 155 - 162.

Van Zyl, J.L., 1984a. Interrelationships among soil water regime, irrigation and water stress in the grape vine (*Vitis vinifera* L.). PhD thesis, Stellenbosch University, Private Bag X1, Matieland 7602, South Africa.

Van Zyl, J.L., 1984b. Response of Colombar grape vines to irrigation as regards quality aspects and growth. S. Afr. J. Enol. Vitic. 5, 19 - 28.

Van Zyl, J.L. & Fourie, A., 1988. Estimating the irrigation requirements of vineyards using crop facors and the Class A-Pan. Farming in South Africa, VORI 227/1988 Dept. of Agricultural Development, Private Bag X144, Pretoria 0001, South Africa.

Zeeman, A.S., 1981. Oplei. In: Burger, J.D. & Deist, J. (eds.). Wingerdbou in Suid-Afrika. Nietvoorbij, Stellenbosch, South Africa, pp. 185 - 201.

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Seasonal vine mealybug phenology in different grape-growing areas in the Western Cape

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Vaughn Walton

Introduction

Vine mealybug (VMB), Planococcus ficus (Signoret), is a polyphagous pest attacking a wide range of different host plants (Ben-Dov 1994). The damage inflicted by VMB on vineyards is well documented (Walton & Pringle 2005, Daane et al. 2004) and vineyard infestations often lead to direct crop losses. VMB can also vector the vine leafroll virus which can be detrimental to high quality wine producers (Cabeleiro & Segura 1997) as crop quality is lower from vines infected with this virus.

VMB control previously focused on the use of synthetic pesticides (Walton et al. 2004, Daane et al., 2006), biological control (Daane et al. 2004, Walton 2003) and more recently mating disruption trials that have been conducted both in Californian and South African vineyards (Walton et al. 2006). VMB control currently relies heavily on the use of synthetically produced pesticides (Daane et al 2005). Control with the use of these pesticides however has its disadvantages such as the disruption of natural enemies of VMB (Walton and Pringle 2001, Walton and Pringle 1999) and it may be ineffective due to the cryptic lifestyle of VMB (Walton 2003). This characteristic leads to the fact that a huge portion of the seasonal on-vine VMB population is found under the bark and in crevices on the main trunk and cordon and roots on vines. These VMB colonies are often protected from the effects of pesticide applications due to the shielding effect of the thick bark layers. Further to this, VMB pest colonies consist of overlapping generations (Walton 2003) throughout the year and all stages of this pest can be found at any time during the year. This phenomenon makes it impossible to time sprays when the susceptible first instars stages occur. Pesticide interventions are therefore timed during periods when applicators can most effectively reach the existing VMB colonies with high pressure equipment using high volumes of pesticides. For these reasons, applications are done during the late-dormant

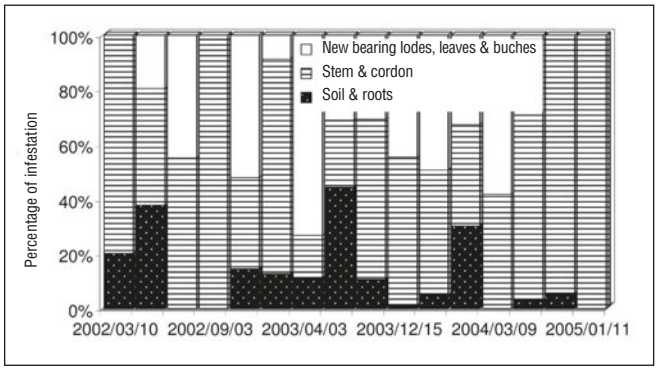

FIG 1a: Vine Mealybug infestations of different plant parts over three seasons in McGregor.

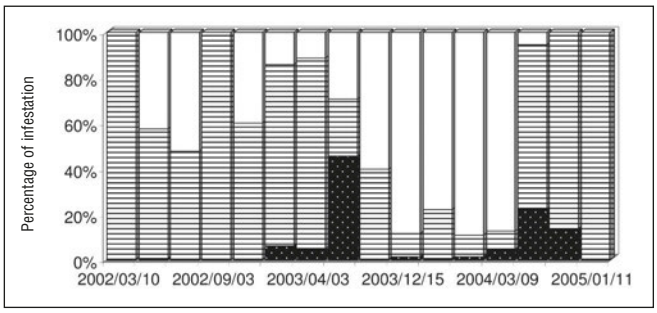

FIG 1b: Vine Mealybug infestations of different plant parts over three seasons in Robertson.

period as well as during the early part of the growing season. During these periods, seasonal shoot and leaf growth affect the penetration of pesticide sprays only to a limited degree. Abovementioned synthetic pesticide sprays are applied as delayed-dormant controls with organophosphates such as chlorpyrifos, applied just before bud break (Walton et al. 2004). In-season sprays include early-season contact organophosphates. During the latter part of the season, corrective short-residual organophosphates are applied in order to clear infested bunches of VMB. In cases where infestations are severe enough to warrant long-term vine damage, post harvest applications of organophosphates are made in order to prevent vines from deterioration due to high VMB damage levels.

The fact that VMB also occurs on the roots of vines indicate that chemical control as used in the past may not be effective to control this important vector of the vine leafroll virus. It is known that conventional chemical control only partially succeed to control P. ficus on the more exposed plant parts (Daane et al. 2006). No investigation has yet been done as to determine the importance of underground VMB populations in different grapegrowing areas in the Western Cape. The goal of this study was to observe VMB population levels on different parts of the vine in order to highlight differences in each grape-growing area. In addition, we attempted to determine which currently available chemical control methods worked best to control these populations.

Materials and methods:

One vineyard in each of three grape growing areas, McGregor, Robertson and Stellenbosch, each with a history of mealybug infestation was used for field surveys and these were routinely investigated on a monthly basis for VMB population levels. Each trial site was designed to contain six treatments and three repetitions in a randomised block design. Each repetition contained three vines and the middle vine was used for data collection on the sampling dates.

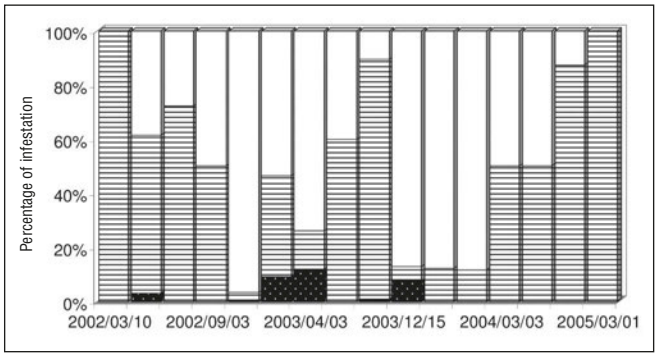

FIG 1c: Vine Mealybug infestations of different plant parts over three seasons in Stellenbosch.

These vines were thoroughly searched in order to investigate seasonal changes of VMB population levels found on different positions of the vine. Sampling on un-treated vines are presented for three seasons, i.e. 2002/2003, 2003/2004 and 2004/2005.

The samples were taken on six plant parts but these data were pooled into three general plant areas in order to simplify the findings and all mealybugs were recorded in each of these areas. The three on-vine areas can be described as follows:

1. The ground and root area: These areas included the root area with a horizontal radius of up to 0.5m away from the main stem and between 0.05 and 0.3 m below the natural soil level. The ground area included the main stem which was searched approximately 5cm above and below the natural soil level.
2. The trunk and cordon area included the whole of the main stem and remaining wood more than one season old.
3. New canes, leaves and bunches included all new shoots that developed during the current season, at least ten leaves and at least ten bunches were inspected for mealybug infestation.

Chemical treatments:

The chemical treatments were done with different goals: The first goal was to test pesticides which would have minimal environmental impact (Treatments 1, 2 & 3). The second was aimed at 100% VMB control as needed in quarantine blocks (Treatments 4 & 5). During 2003/2004 and 2004/2005 the different chemical treatments included:

1. A single in-season mevinphos SL 500g/L (Mevinphos, contact insecticide) treatment at 45 mL/100L concentration
2. An unregistered organic soap/oil mixture (Prev Am) at 0.5mL/L
3. An unregistered organic soap/oil mixture (Prev Am) at 0.25mL/L 4
4. A single acetamiprid SP 200g/L (Mospilan, systemic insecticide) full-cover application
5. Imidacloprid 350SC (Confidor, systemic insecticide) was soil applied treatment at 1.5mL/vine in 500mL during November 2003 only.
6. An untreated control.

During 2003/2004 and 2004/2005, the non-systemic pesticides were applied during the early to middle of November in 2003 and 2004 respectively. These applications were timed based on VMB population levels and degree-days (DD) estimates. Chemical applications were made as soon as the first VMB populations were found on vines and the estimated accumulated number of DD was equivalent to the development of one VMB generation. Only one systemic pesticide application was done during early October 2003 over the two seasons as there was evidence of a carry-over effect to the following season in previous trials. The current cost of these systemic pesticides are relatively high and the application methodology labour intensive, for these reasons applications during consecutive seasons would be unlikely.

Results and discussion:
Monitoring of mealybug infestation levels on different plant parts:

During the three seasons, higher summer and lower winter temperatures were recorded in McGregor and Robertson compared to Stellenbosch. Stellenbosch generally has wet winters compared to the other two regions. Sandy soils were found in McGregor, Stellenbosch had loamy clayey soils and Robertson had clayey soils.

McGregor had the highest VMB infestations in the ground and roots, followed by Robertson and Stellenbosch which had the lowest numbers (Figs. 1a-c). We believe that the higher P. ficus populations in McGregor could be due to the sandy soils found here. Sandy soils are associated with bigger areas between soil particles and less water logging during wet periods due to lower water retention properties. This could lead to higher levels of available oxygen which would be necessary for subterranean P. ficus populations to survive. In Stellenbosch, roots were colonized for relatively short periods compared to the other areas. This could be a symptom of water logging during wet winter periods in this region. Waterlogging could lead to destruction of VMB populations during wet periods, followed by subsequent re-colonising during dry summer periods.

Data from the three areas and seasons indicate that the largest portion of the P. ficus populations on vines occur on the protected trunk area. This protection is provided by thick bark layers which provides the most suitable micro-habitat for mealybug populations. Areas under the bark provide protection from extreme environmental conditions, chemical sprays and natural enemies. The main trunk and old canes are also less disturbed during pruning and harvest and the phloem on the main trunk is within easy reach of the mouthparts of mealybugs and provides a year-long nutrient source for VMB pest infestations. Many producers have found that younger vineyards which have virtually no bark are usually not associated with heavy mealybug pest infestations. The reason for this could be due to less availability of preferred and protected feeding sites. In Stellenbosch vines did not have thick layers of bark and provided less refuge and feeding sites for mealybugs. Here mealybug populations more readily colonised new cane, leaf and bunch areas. A larger proportion of the total VMB populations were found on these areas compared to Robertson and McGregor where thicker bark permitted a larger portion of the VMB population to colonize the trunk and cordon areas. The above trends lead us to believe that non-systemic chemical control should be targeted towards the trunk and cordon of vines in order to kill the majority of the P. ficus populations on vines.

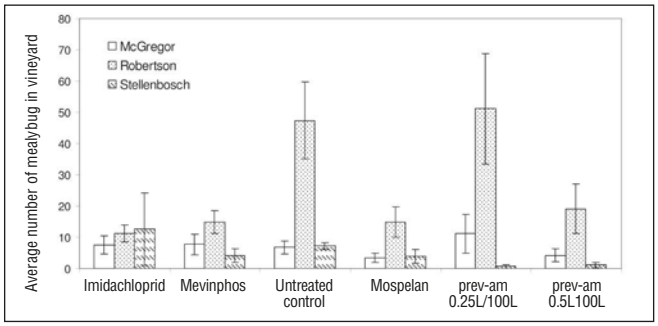

FIG 2a: Mean number of vine mealybugs in three grapegrowing areas using different chemical treatments.

New canes, leaves and bunches are often colonized during the beginning of summer up to harvest and it is during this period that mealybug populations are noticed for the first time due to the fact that they are clearly visible without the need to peel bark off the trunk. Chemical control can however be extremely difficult during this period due to the dense leaf cover which often results in mealybug colonies escaping contact from pesticides. For these reasons, the use of chemical sprays during this period is not recommended.

Chemical treatments:

Factorial ANOVA analysis of data indicated differences of VMB infestations and the highest infestations were found in Robertson (Fig. 2a). Significant higher VMB counts were found in the untreated control and prev-am (0.25L/100L) plots compared to the other treatments. Some suppression was found in the remainder of the treatments. The root-applied systemic pesticide (Imidachloprid) resulted in the highest levels of VMB suppression compared to the other treatments but differences were not significant.

The main focus of the systemic chemical treatments was to achieve 100% control of VMB but this goal was however not achieved as the above treatments never reached these levels of control (Fig. 2). These results were however expected as the level of VMB control was similar to those found from work done on VMB in California. Systemic treatments showed indications of a carry-over effect from the previous season. Systemic pesticides therefore provide VMB suppression for more than one season and prevent economic crop losses. These chemicals however do not succeed in total elimination of VMB populations from vines. Bunches were lost only in Robertson in the control and Prev-Am (0.25) treatments during 2004/2005. This leads us to believe that these treatments will not be effective when high levels of VMB infestation are found. The remainder of chemical treatments however prevented economic crop losses.

Conclusions:

Trends in the three year study indicate that VMB can colonize roots and dry sandy conditions are most suitable for root colonization. We found the biggest portion of VMB populations under the bark on the trunk and cordon areas. Chemical control was never sufficient to provide 100% VMB control. These facts indicate the importance of an IPM approach to control this key pest. This approach includes regular monitoring, the enhancement of biological control through ant control, limitation of dust, release of commercially available natural enemies as well as limited chemical control based on reliable monitoring data.

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References:

Ben-Dov Y., 1994. A systematic catalogue of the mealybugs of the world (Insecta: Homoptera: Coccoidea: Pseudococcidae and Putoidae) with data on geographical distribution, host plants, biology and economic importance. Intercept Limited, Andover, UK. 686 pp.

Daane, K. M., Bentley, W. J., Walton, V. M., Malakar-Kuenin, R., Millar, J. G., Weber, E. A., Gispert, C., 2006. New controls investigated for vine mealybug. California Agriculture, January-March 2006, Vol. 60, No.1, pp.31-38.

Daane K.M., Bentley W.J., Walton V.M., Malakar-Kuenen R., Yokota G.Y., Millar J.G., Ingels C.A., Weber E.A. & Gispert, C. 2005. New controls investigated for vine mealybug. California Agriculture, Volume 60 Number 1, 31-38.

Daane K.M., Malakar-Kuenen R.D. & Walton V.M. 2004. Temperature-dependent development of Anagyrus pseudococci (Hymenoptera: Encyrtidae) as a parasitoid of the vine mealybug, Planococcus ficus (Homoptera: Pseudococcidae) Biological Control 31: 123-132

Cabaleiro C. & Segura A. 1997. Field transmission of grapevine leafroll associated Virus 3 (GLRa V-3) by the mealybug Planococcus citri. Plant Disease 81: 283-287.

Walton V.M. & Pringle K.L. 2001. The effects of pesticides and fungicides used on grapevines on the mealybug predatory beetle Nephus boschianus (Coccinellidae, Scymnini). South African Journal of Enology and Viticulture 22(2), 107-110.

Walton V.M. & Pringle K.L. 1999. Effects of pesticides used on table grapes on the mealybug parasitoid, Coccidoxenoides peregrinus (Timberlake) (Hymenoptera: Encyrtidae. South African Journal of Enology and Viticulture 20(1), 31-34.

Walton,V.M. 2003. Development of an integrated pest management system for vine mealybug, Planococcus ficus (Signoret), in vineyards in the Western Cape Province, SouthAfrica. Ph.D. dissertation, University of Stellenbosch, Stellenbosch.

Walton V.M., Daane K.M. & Pringle K.L. 2004. Monitoring Planococcus ficus in South African vineyards with sex pheromone-baited traps. Crop Protection 23, 1089- 1096.

Walton, V. M., Daane, K. M., Bentley, W. J. , Millar, J. G., Larsen, T. E., Malakar Kuenin, R., 2006. Pheromone-based Mating Disruption of Planococcus ficus (Hemiptera: Pseudococcidae) in California Vineyards. Journal of Economic Entomology 99(4): 1280-1290.

Walton, V.M. & Pringle, K.L., 2005. Developmental biology of vine mealybug, Planococcus ficus (Signoret) (Homoptera: Pseudococcidae), and its parasitoid Coccidoxenoides perminutus (Timberlake) (Hymenoptera: Encyrtidae). African Entomology 13(1):143-147.

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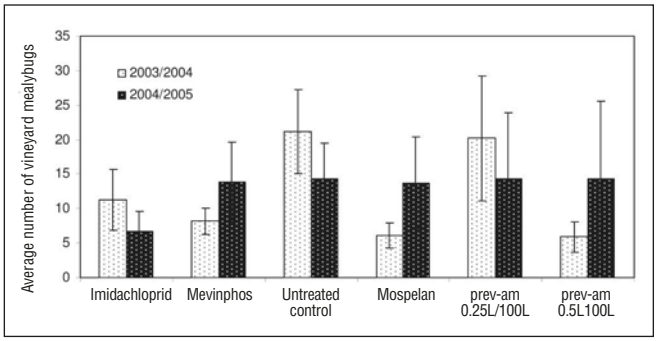

FIG 2b: Mean number of vine mealybugs in three grapegrowing areas over three seasons using different chemical treatments.

Reasons and procedures for soil preparation

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Braham Oberholzer

Introduction

What time of the year, with which implement and to what depth should soil preparation take place? Has soil preparation not become a routine procedure like so many others in the vineyard, inter alia fertiliser applications? Do we still pause to query the type of soil and its characteristics?

Most important of all is to understand the reasons for soil preparation. The emphasis should be on alleviating soil compaction, i.e. to increase porous space and reduce bulk density. Texture is without any doubt the most important soil characteristic, seeing that many other soil characteristics derive from it. Texture provides the building blocks for structure and any action that destroys structure should be banished.

Once we have decided on soil preparation, be it for chemical or physical reasons, we need to determine what procedures are to be followed? The following reasons and procedures for soil preparation should persuade you to use common sense when thinking and making decisions about your soil.

Reasons for soil preparation

Western Cape soils are inherently dense/compact, or acidic, especially in the subsoil. The reasons being that the age of the parent material is much older than for example in countries such as Australia and America. Malmesbury shale is between 55-1 000 million years (Ma) old, Cape granite between 500-600 Ma and Table Mountain sandstone between 300-400 Ma old. By contrast the Bordeaux reddish and yellowish brown foothill soils of France are probably ± 50 Ma and alluvial gravels less than 2Ma old (D.Saayman, 2006 personal communication).

There is also a high degree of weathering of the parent material, accompanied by the loss of basic cations that have been replaced by nitrogen and that release toxic aluminium. Loam minerals, mainly kaolin, illite and sesquioxides, with low exchange capacity of 3 – 5cmol(+)/kg-1, are formed, in contrast with the young and alluvial soils' exchange capacity of 10 – 25cmol(+)/kg-1.

In general the limited depth and poor physical structure of most grapevine soils require intensive soil preparation. Restrictive layers are broken up to depths of 800 - 1000 mm to make large soil volumes available for root growth and give the soil an improved buffer ability against the influence of unfavourable climatic and nutritional conditions.

In his extensive soil preparation studies Van Huyssteen (1988) regularly emphasised the advantages of preparing the soil to the required depth. By doing so, the soil is able to integrate climatic effects such as water retention, drainage and soil temperature. Effective soil preparation with the appropriate implements is able to create a homogeneous root medium, which promotes uniform root distribution throughout soil depth. As a result manipulations above the ground, such as pruning, trellising, plant width and crop load, can be more flexible. The general recommendation is to loosen grapevine soil with subsoil problems to a depth of at least 800mm so that the soil appears homogeneous.

Recent international articles emphasise the fact that grapevine root functioning through poor soil physical qualities seriously hampers the nutritional uptake of the grapevine (Cass, 2006). In general significant uptake of water takes place between field capacity and wilting point, but certain unfa-

FIG 1: Double-wing finger mix delve plough.

FIG 2: Oakleaf soil type before cultivation with obvious above-ground and subsoil horizons.

vourable factors such as high soil strength, high water content and poor aeration may reduce the spectrum of water availability.

Soil penetration resistance with values of 2 Mpa is generally accepted to be the absolute limit for grapevine root penetration. Phosphorus and potassium uptakes in particular are sensitive to the degradation of soil physical characteristics due to their dependency on short distance diffusion and the necessity for relatively high soil moisture content.

Where massive compaction in the subsoil occurs in soil types such as Glenrosa, Oakleaf, Hutton and Clovelly, these soils will react well to soil preparation with regard to root growth, vigour and production. A less obvious, but very real problem regarding these soils is excessive acidity, especially in the subsoil. With finger mix delve plough (Fig. 1) as used in the accompanying figures 1 & 2, the ideal mixture of soil above and below the surface is obtained.

Procedures for soil preparation:

To implement once-off, correct preparation for the perennial grapevine, these procedures should be followed:

- **Soil analyses:**
  Chemical adjustments, for example the application of the right amount of lime to adjust the soil's pH, as well as the phosphorus status, go hand in hand with soil preparation. The accompanying fig.4 clearly shows the importance of adjusting soil pH in order to enable the root development of rootstocks to function optimally. In most instances soil that had been limed to a pH of 6 significantly increased the root mass of rootstocks.
- **Soil profile inspection:**
  It is necessary to make profile pits for soil classification so that one can judge which cultivation method is required. Nowadays there is excellent collaboration between earthmovers and soil scientists, the latter often being requested, with the approval of the producer, to first view or classify the soil. Neat profile pits (Fig.5) up to a depth of 1500mm and deeper offer very good decision making ability.

3. **Implement selection:**
   The next step is to decide whether preparation should take place with a bulldozer/caterpillar (Fig. 6). Tractors are no longer suitable for deep soil preparation, seeing that their soil surface contact is insufficient, there is not sufficient power available on the soil and if used, slipping wheels could add to soil compaction. Caterpillars are the only source of power that can be used successfully. Caterpillars displace more power to the soil with less compaction due to the larger soil surface contact area of the caterpillar tyres.
4. **Type of mix:**
   Currently the use of digger loaders, known as "spit" (delve), is definitely an option to consider. It is very important to use large machines and ensure that correct techniques are implemented. If layers occur due to, inter alia, drastic differences in texture (duplex soils), a digger loader should be used with caution, since it mixes layers, and one would prefer finger mix delve plough, which keeps layers in position.

   It is necessary to determine the furrow width (width between the plough-shares) of a ripper well in advance,

FIG 3: The same Oakleaf soil type after double finger mix delve plough. Note the good mixture of above-ground soil and subsoil.

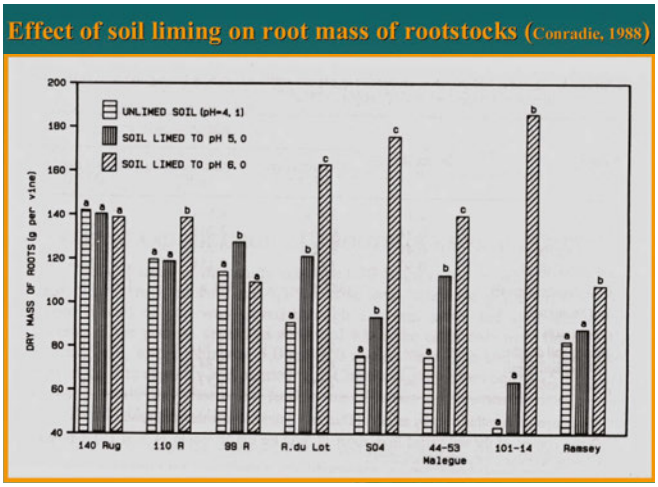


FIG 4: The effect of liming on the root mass of rootstocks as indicated by Conradie (1988).

FIG 5: This profile pit at Darling has a neat walk-in space and is wide enough to turn around in so that one may study soil preparation and root growth, as demonstrated by Leon Dippenaar at the 2006 Swartland vineyard block competition. The profile, however, could have been deeper and closer to the vines (300mm).

FIG 6: Digger loader with 1,5 metre size bin. (Photo: Johan Nolte)

FIG 7: A soil ball forms when it is rolled, only to fall apart with a single pressing action.

Table 1: Price per hectare for various implement/cultivation options (Price list for soil preparation for 2007).

Ripper with 90 cm furrow width and depth ± 1,2 m	**R6 800**
Ripper with 1,1 m furrow width and depth ± 1,2 m	**R5 250**
Ripper with 3 toe depth ± 90 cm	**R3 000**
Ripper with 2 toe depth ± 90 cm	**R3 600**
Shift plough with furrow width 55 cm and depth 1,2 m	**R7 500 - R9 200**
Shift plough with furrow width 75 cm and depth 1,2 m	**R6 000 - R7 500**
Spit delve with digger to clear on the rows only	**R9 500 - R11 500**
Spit delve on the rows only and ridging	**R16 500 - R18 000**
Spit delve full surface	**R13 500 - R21 000**
D6R with drawn plough: Furrow widths 55 cm – 75 cm and depth 1,1 m	**R4 000 - R6 000**
Ripping out grapevines with wing	**R2 000 - R2 200**
Trencher to uproot fruit trees	**R1 800 - R2 500**
Diesel consumption for ripping and trenching per hectare is 37% of cost per hectare.	
TRANSPORT COSTS	
Transport cost of D9R caterpillar	**R3 600 - R4 500**
Transport cost of D8R caterpillar	**R2 500 - R3 600**
Transport cost of D6R caterpillar	**R2 500 - R3 000**
Transport cost of digger louder	**R2 000 - R2 500**

mainly due to cost implications (Table 1) and the necessity thereof. If you want to avoid large lenses of undisturbed soil between the furrow widths, this will have to be a careful decision. With a cross action the lenses can usually be reduced. If cultivation takes place to a depth of 900mm, the furrow should be ?, i.e. 600mm.

- Period of soil preparation
  The period of soil preparation is of the utmost importance. In excessively dry soil large clods will break, especially on the surface, which creates an undesirable situation when the soil is trenched. For example, a ball of soil (Fig 7) should be able to be rolled and then fall apart with the slightest of pressure for the soil climate to be suitable for cultivation. Climate and lime requirement will then determine whether the soil should be cross-delved or alternatively require a single action. Wetting of the soil for 4 hours with sprinkler irrigation, applying ± 25mm water, and allowing for 48 - 72 hours' drying out, will limit the formation of large clods.
- Cost implications:
  The motivation for soil preparation is and remains a long term input, initially rather expensive, but the long term objective is that the grapevine will benefit from this action for approximately 20 years. Table 1 gives us an indication of the possible difference in costs of various options.

Summary:

The following should be kept in mind at all times:

- Excessive tillage can result in destruction of the structure and the soil, when dry, will have been tilled to a powdery matter.
- Excessively wide furrow widths result in poor mixing with large untouched soil banks/lenses.
- Cultivation row should be selected correctly with a view to subsoil drainage.
- The soil climate should be correct; too dry will form large clods; too wet will smear the subsoil.
- Regular evaluation of soil preparation is essential. That means making regular profiles (keep trencher handy) so that progress and quality may be judged by the experts.

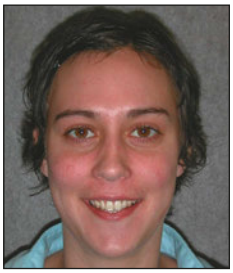
Literature references:

Cass, A., 2006. Poor soil physical properties can hinder nutrient uptake in vines. The Australian & New Zealand Grapegrower & Winemaker pp 19-22.

Conradie, W.J., 1988. Effect of soil acidity on grapevine root growth and the role of roots as a source of nutrient reserves. Technical Communication no. 215. Viticultural and Oenological Research Institute, Stellenbosch. Republic of South Afirka. Department of Agriculture and Water Supply.

Van Huyssteen, L., 1988. Soil preparation and grapevine root distribution - A qualitative and quantitative assessment. Technical Communication no. 215. Viticultural and Oenological Research Institute, Stellenbosch. Republic of South Africa. Department of Agriculture and Water Supply

Molecular detection of potential inoculum sources of *Phaeomoniella chlamydospora* in grapevine nurseries



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Key words: Black goo, Petri disease

Introduction

Petri disease (previously known as "Black goo") is a common occurrence on grapevines aged one to five years (Fourie et al., 2000). The disease reduces the chances of survival of young grapevines (Mugnai et al., 1999). External symptoms of Petri disease are stunted growth, shortened internodes, small leaves, and a general deterioration of young vines which may result in the plant's dying (Morton, 1995; Bertelli et al., 1998; Ferreira, 1998; Fourie et al., 2000; Sidoti et al., 2000; Whiteman et al., 2003). Internal symptoms include a black discolouration of the xylem vessels, as well as tyloses formation (balloon-like growths) in these vessels (Ferreira, 1998). Phaeomoniella chlamydospora is considered to be the main causal organism (Fourie and Halleen, 2001; Wallace et al., 2003; Whiteman et al., 2003).

Not much is known about the epidemiology of P. chlamydospora, although a few sources of inoculum have been identified. Spores of P. chlamydospora have been captured in vineyards in California and France (Larignon, 1998; Eskalen et al., 2003). From these it was possible to deduce that the fungus produces spores (conidia) that are distributed aerially and penetrate the grapevine mainly through pruning wounds (Larignon, 1998; Eskalen et al., 2003).

Infected rootstock mother plants and propagation material are considered to be primary inoculum sources, as isolations have shown the pathogen to be present in apparently healthy rootstock mother plants (Fourie and Halleen, 2004a) and cuttings (Bertelli et al.,1998; Larignon, 1998; Fourie and Halleen, 2002; Halleen et al., 2003). Spores and/or hyphal fragments of P. chlamydospora have been found in the entire length of rootstock canes (Feliciano en Gubler, 2001; Edwards et al., 2003) and one wonders whether the spores might be transported to the canes in the juice flow of infected rootstock mother plants (Edwards et al., 2003).

Infested soil is also considered a potential source of inoculum, as P. chlamydospora has been detected in nursery and vineyard soil by means of a conventional species- specific PCR (polymerase chain reaction) (Damm and Fourie, 2005). If P. chlamydospora forms hardy spores (chlamydospores), the fungus may survive in the soil for long periods. One expects chlamydospores to form conidia, which will then infect damaged roots of grapevines in nurseries and grapevines (Bertelli et al., 1998; Feliciano and Gubler, 2001).

During the propagation process of grapevines there are various stages at which P. chlamydospora may infect the host. One of the first stages at which infection may take place is when the rootstock and scion cuttings are harvested and drenched in hydration tanks for a period of 12 hours, prior to cold storage (Van der Westhuizen, 1981). After cold storage the cuttings will undergo a rehydration process either before and/or after grafting, during which they are drenched in water or a fungicide suspension. In South Africa grafted vines are placed in a callusing medium consisting of fresh pine sawdust that has been drenched in a broad-spectrum fungicide suspension (Van der Westhuizen, 1981).

It is difficult to detect P. chlamydospora using traditional isolation methods, due to the slow growth of the fungus and a lack of selective media. For this reason a conventional PCR technique was devised to detect P. chlamydospora in grapevine wood (Retief et al., 2005). The technique is sufficiently sensitive to detect 1 pg P. chlamydospora DNA (deoxyribonucleic acid) in grapevine wood, but not sufficiently sensitive to detect the DNA of the fungus in soil and water. A similar technique has been used in New Zealand and P. chlamydospora was detected during all the nursery stages - especially in drench solutions, where there was repeated exposure to plant material, e.g. in hydration tanks. The percentage of positive samples was lower for grafting equipment and callusing media (Whiteman et al., 2003).

The first objective of this study was to finetune DNA extraction and conventional PCR techniques that had previously been developed and optimised for grapevine wood and soil (Damm and Fourie, 2005; Retief et al., 2005), for molecular detection in water and callusing medium.

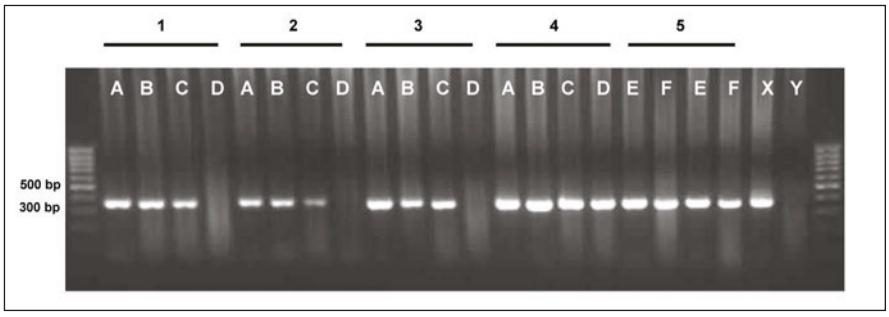

FIG 1: Determination of the sensitivity of the one-tube nested PCR with primers Pch1 and Pch2: DNA from grapevine wood **(1)**, callusing medium **(2)**, soil **(3)** and water **(4)**, that tested negative for P. chlamydospora and to which specific amounts [1 pg **(A)**, 100 fg **(B)**, 10 fg **(C)** and 1 fg **(D)**] of P. chlamydospora genomic DNA had been added; and 90 ml water samples **(5)** to which 102 spores **(E)** and 101 spores **(F)** had been added. The 100 bp DNA ladder is far left and right. A positive control **(X)** containing only genomic DNA and a negative control **(Y)** containing no template, are included.

The subsequent objective of the study was to use these molecular techniques to determine whether P. chlamydospora was present in samples (water, soil, graft wood and callusing medium), collected from different nurseries and at different stages, in order to identify the different inoculum sources of the fungus during the various nursery stages in South Africa.

Material and methods

Sampling: Rootstock canes of the cultivars 101-14 Mgt, Ramsey, 99 Richter and 110 Richter were collected from the rootstock mother plants at six nurseries. Rootstock cuttings (101-14 Mgt and Ramsey) and scion cuttings (various cultivars) were also collected from 16 and 19 different nurseries respectively during the grafting process.

Soil samples were taken from the root zone of the mother plants, from which the rootstock canes had been collected. Soil samples were also taken from the prepared nursery beds at 18 nurseries just before planting out occurred.

During the first hydration (before cold storage) two water samples each were collected from 15 different nurseries. The one sample was water from the hydration tank in which rootstock cuttings had been drenched for a period of 12 hours. The other sample was taken from the water source (that supplies water to the hydration tank), in order to determine whether the water source was contaminated. Water samples were also taken from 21 nurseries during the second hydration, during the grafting process (before grafting or just before callusing).

During the grafting process callusing medium was collected from 12 nurseries. The samples were taken before the callusing period, in other words before the grafted cuttings were packed in the callusing medium and before the latter was drenched in a fungicide suspension.

Molecular detection: DNA was extracted from the soil and wood using the extraction protocols that had already been developed (Damm and Fourie, 2005; Retief et al., 2005). Different aspects of the latter protocols were used to design new protocols for DNA extraction from water and callusing medium. For the DNA extraction from water 90 ml of water was centrifuged in a centrifuge to collect all material at the bottom of the tube. The remaining fluid was discarded, and a CTAB extraction buffer added to the material to form a suspension. Thereafter glass balls were added to the suspension, and it was shaken to break the cell walls for DNA extraction. Subsequently the same protocol as for DNA extraction from wood was followed. DNA extraction from the callusing medium took place firstly by breaking the cells. The cells were broken by rapidly shaking the callusing medium and glass balls that had been frozen with liquid nitrogen. A CTAB extraction buffer was then added and the same protocol as for DNA extraction from wood was followed.

A one-tube nested-PCR technique (Olmos et al., 1999) was then used in combination with species-specific primers to detect P. chlamydospora in water, soil, graft wood and callusing medium. With a nested-PCR all fungal DNA is firstly multiplied from the sample, whereafter a PCR is done with the species-specific primers Pch1 and Pch2 (Tegli et al., 2000) for P. chlamydospora DNA. By doing the entire process in a single tube, the chances of contamination are drastically reduced.

The sensitivity of the PCR reaction was determined by adding known quantities of P. chlamydospora DNA (as determined with a fluorometer) to a DNA solution, consisting of DNA extractions from wood, soil, water and callusing medium, which had tested negatively with the P. chlamydospora specific primers (Pch1 and Pch2) in the past. To determine how many spores may be detected in water samples, spore suspensions of P. chlamydospora were added to water samples to obtain final concentrations of 101 and 102 conidia in 90ml of water, thereafter the DNA was extracted from these samples.

The identity of PCR products obtained, using P. chlamydospora specific primers, was confirmed by restriction enzyme analysis and DNA sequencing.

Results

The nested-PCR was sensitive enough to detect 1 fg P. chlamydospora genomic DNA from water and 10fg from the callusing medium, wood and soil. It was also possible to detect as few as 10 spores in a water sample of 90ml (Fig. 1).

Samples that tested positively for P. chlamydospora were rootstock canes collected from mother plants (25%), rootstock cuttings collected during grafting (42%), scion cuttings collected during grafting (16%), water samples collected during the first hydration before cold storage (40%), water samples collected during grafting (67%), callusing medium (8%) and soil samples collected from rootstock mother blocks (17%) (Fig. 2). However, P. chlamydospora was not detected in soil samples from nursery beds before planting. Various PCR products were obtained using the one-tube nested-

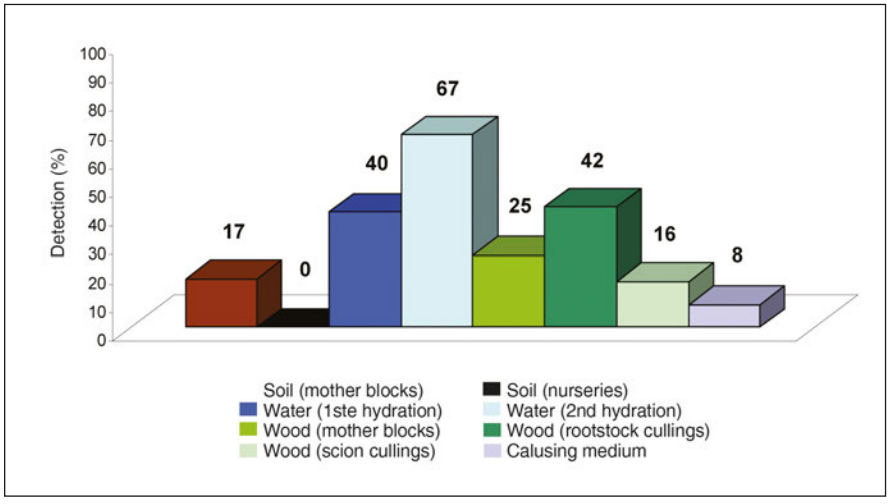

FIG 2: Detection percentages of *P. chlamydospora* in wood, water, soil and callusing medium collected during the different nursery stages. *P. chlamydospora* was detected by using *P. chlamydospora* specific primers and a one-tube nested-PCR. The P. chlamydospora identity of all PCR products was confirmed by means of restriction enzyme analysis and DNA sequencing.

PCR, whereafter it was confirmed by means of restriction enzyme analysis and/or DNS sequence determination that the products were indeed P. chlamydospora. P. chlamydospora in mother blocks was detected mostly in 101-14 Mgt (13%) and 99 Richter (8%), as opposed to Ramsey (4%) and 110 Richter (0%). During grafting P. chlamydospora was also detected mostly in 101-14 Mgt (24%) as opposed to Ramsey (18%).

Discussion

In support of previous studies, it was once again confirmed that infected mother plants and cuttings are the primary inoculum source, in that a quarter of the rootstock canes from mother plants tested positively for the presence of P. chlamydospora. The rootstock canes 101-14 Mgt had the highest percentage of infected canes which correlates with the findings of Fourie and Halleen (2004a), who used conventional isolation techniques.

Infested soil should also be considered a potential inoculum source, as P. chlamydospora DNA was also detected in soil samples taken from mother blocks. P. chlamydospora may be present in the soil as mycelium, conidia, chlamydospores and/or other fruit structures, deriving from infected mother plants. The long term survival of this fungus in the soil is nevertheless questioned seeing that it could not be detected in soil samples from nursery beds after a one year period of lying fallow. Another possible explanation for this absence is the levels of the pathogen being so low as to make it impossible to detect through PCR.

Water samples taken before cold storage, during grafting and from fungicide tanks, also tested positively for the presence of P. chlamydospora. None of the water samples taken from the water sources tested positively for the pathogen, which proves that the water source is not a source of inoculum. After a hydration period of 12 hours the water was contaminated, however, most probably due to contaminated cuttings. The contaminated hydration water is therefore a very important source of inoculum, seeing that all cuttings undergo the hydration process before cold storage. Similar results were also obtained in New Zealand (Whiteman et al., 2003). Sanitation practices, as recommended by Fourie and Halleen (2006a,b), are therefore of the utmost importance in this regard.

From the results with rootstock cuttings it seems that the number of infected samples increased during the nursery process, from 25% in mother plants to 42% during grafting. The same material was not used in these instances, however, and further samples will have to be analysed to confirm this preliminary conclusion. Scion cuttings (16%) also tested positive for P. chlamydospora during grafting. Just like rootstock cuttings, these cuttings may be infected during hydration or possibly from infected mother plants.

A very small number of the callusing medium samples (8%) tested positive for P. chlamydospora. Callusing medium consists mainly of pine sawdust and it is not known whether P. chlamydospora occurs on pines. This might indicate that the callusing medium was contaminated during the nursery stages, most likely from contaminated water, utensils or floors.

Several potential inoculum sources were identified during the study. By applying the correct control measures, the inoculum may be reduced or even killed. Up to now warm water treatment (30 min at 50°C) of propagation material before grafting has been proven most effective in reducing P. chlamydospora levels in naturally infected rootstock cuttings (or dormant nursery plants) (Fourie and Halleen, 2004b).

Hydration tanks are also an important focus of control strategies. Hydration tanks must be sterilised after each hydration and the water in which cuttings are immersed must be treated with chemical and/or biological control agents, since uncovered pruning wounds on cuttings provide the perfect point of entry for P. chlamydospora (Messina, 1999; Fourie et al., 2001; Fourie and Halleen, 2004b). South African nurseries use broad spectrum contact fungicides such as chinosol, captan and/or iprodione in hydration tanks, but these fungicides were shown to be moderately or poorly effective at reducing in vitro germination and mycelium growth of P. chlamydospora (Groenewald et al., 2000; Jaspers, 2001). Recent semi-commercial nursery trials by Fourie and Halleen (2006a, b) indicated that the use of benomyl (100g/100L water) or Sporekill (150mL/100L water) in hydration and drench water during all stages of preparation and grafting of propagation material, resulted in the biggest reduction in infection levels of P. chlamydospora.

The detection of P. chlamydospora in this study was based on the presence of the pathogen's genomic DNA. It is therefore important to take into account that the presence of the pathogen's DNA does not confirm the pathogen to be viable. Further studies will therefore have to focus on the detection of RNA (ribonucleic acid). Theoretically transcripts of RNA will have a very short survival period once the pathogen has been killed. RNA detection is therefore only possible from live organisms (Klein and Juneja, 1997).

Acknowledgement

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Literature

Bertelli, E., Mugnai, L. and Surico, G., 1998. Presence of Phaeoacremonium chlamydosporum in apparently healthy rooted grapevine cuttings. Phytopathologia Mediterranea 37, 79 - 82.

Damm, U. and Fourie, P.H., 2005. Development of a cost-effective protocol for molecular detection of fungal pathogens in soil. South African Journal of Science 101, 135 - 139.

Edwards, J., Pascoe, I.G., Salib, S. and Laukart, N., 2003. Phaeomoniella chlamydospora and Phaeoacremonium aleophilum can spread into grapevine canes from trunks of infected mother vines. In 3rd International Workshop on Grapevine Trunk Diseases, Lincoln, New Zealand, pp. 29.

Eskalen, A., Rooney-Latham, S.N., Feliciano, A.J. and Gubler, W.D., 2003. Epiphytic occurrence of esca and Petri disease pathogens on grapevine tissues. In 3rd International Workshop on Grapevine Trunk Diseases, Lincoln, New Zealand, pp. 29.

Feliciano, A.J. and Gubler, W.D., 2001. Histological investigations on infection of grape roots and shoots by Phaeoacremonium spp. Phytopathologia Mediterranea 40, S387 - S393.

Ferreira, J.H.S.,1998. Phialophora terugsterwing - 'n Algemene probleem by jong wingerde. Wynboer Tegnies March, T6 - T8.

Fourie, P.H., Halleen, F., Groenewald, M. and Crous, P., 2000. Black goo decline of grapevine. Wynland August, 93 - 96.

Fourie, P.H. and Halleen, F., 2001. Diagnose van swamsiektes en hul betrokkenheid by terugsterwing van jong wingerd. Wynboer 149, 19 - 23.

Fourie, P.H., Halleen, F., van der Vyver, F. and Schreuder W., 2001. Effect of Trichoderma treatments on the occurrence of decline pathogens in the roots and rootstocks of nursery grapevines. Phytopathologia Mediterranea 40, S473 - S478.

Fourie, P.H. and Halleen, F., 2002. Investigation on the occurrence of Phaeomoniella chlamydospora in canes of rootstock mother vines. Australasian Plant Pathology 31, 425 - 426.

Fourie, P.H. and Halleen, F., 2004a. Occurrence of grapevine trunk disease pathogens in rootstock mother plants in South Africa. Australasian Plant Pathology 33, 313 - 315.

Fourie, P.H. and Halleen, F., 2004b. Proactive control of Petri disease of grapevine through treatment of propagation material. Plant Disease 88 (11), 1241 - 1245.

Fourie, P.H. and Halleen, F., 2006a. Chemical and biological protection of grapevine propagation material from trunk disease pathogens. European Journal of Plant Pathology 116, 255 - 265.

Fourie, P.H. and Halleen, F. 2006b. Sanitêre beheermaatreëls vir infeksies deur stampatogene in wingerdkwekerye. Wynboer 206, 12 - 14.

Groenewald, M., Denman, S. and Crous, P.W., 2000. Fungicide sensitivity of Phaeomoniella chlamydospora, the causal organism of Petri grapevine decline. South African Journal of Enology and Viticulture 21, 59 - 61.

Halleen, F., Crous, P.W. and Petrini O., 2003. Fungi associated with healthy grapevine cuttings in nurseries, with special reference to pathogens involved in the decline of young vines. Australasian Plant Pathology 32, 47 - 52.

Jaspers, M.V., 2001. Effect of fungicides, in vitro, on germination and growth of Phaeomoniella chlamydospora. Phytopathologia Mediterranea 40, S453 - S458.

Klein, P.G. and Juneja, V.K., 1997. Sensitive detection of viable Listeria monocytogenes by reverse transcription-PCR. Applied and Environmental Microbiology 63, 4441 - 4448.

Larignon, P.,1998. Esca disease from a European perspective. In Seminar and Workshop on Black Goo Symptoms and Occurrence of Grape Declines ? IAS/ICGTD Proceedings, Napa, USA, pp. 43 - 55.

Messina, J., 1999. The use of beneficial Trichoderma in grapevine propagation. Combined Proceedings of the International Plant Propagator's Society 48, 145 - 148.

Morton, L.,1995. Mystery diseases hit young vines. Wines and Vines 11, 46 - 47.

Mugnai, L., Graniti, A. en Surico, G.,1999. Esca (black measles) and brown wood-streaking: Two old and elusive diseases of grapevines. Plant Disease 83, 404 - 418.

Olmos, A., Cambra, M., Esteban, O., Gorris, M.T. and Terrada, E.,1999. New device and method for capture, reverse transcription and nested PCR in a single closed-tube. Nucleic Acids Research 27(6), 1564 - 1565.

Retief, E., Damm, U., van Niekerk, J.M., McLeod, A. and Fourie, P.H., 2005. A protocol for molecular detection of Phaeomoniella chlamydospora in grapevine wood. South African Journal of Science 101, 139 - 142.

Sidoti, A., Buonocore, E., Serges, T. and Mugnai, L., 2000. Decline of young grapevines associated with Phaeoacremonium chlamydosporum in Sicily (Italy). Phytopathologia Mediterranea 39, 87 - 91.

Tegli, S., Bertelli, E. and Surico, G., 2000. Sequence analysis of ITS ribosomal DNA in five Phaeoacremonium species and development of a PCR-based assay for the detection of P. chlamydosporum and P. aleophilum. Phytopathologia Mediterranea 39, 134 - 149.

Van der Westhuizen, J.H., 1981. Voortplanting. In Burger J. and Deist J. (eds.) Wingerdbou in Suid-Afrika, Maskew Miller, Cape Town, pp. 141 - 168.

Wallace, J., Edwards, J., Pascoe, I.G. and May, P., 2003. Phaeomoniella chlamydospora inhibits callus formation by grapevine rootstock and scion cultivars. In 3rd International Workshop on Grapevine Trunk Diseases, Lincoln, New Zealand, pp. 24.

Whiteman, S.A., Jaspers, M.V., Stewart, A. and Ridgway, H.J., 2003. Identification of potential sources of Phaeomoniella chlamydospora in the grapevine propagation process. In 8th International Congress of Plant Pathology, Christchurch, New Zealand, pp. 94.

The South African Wine Industry – variety is in our nature

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Victoria Carey

The nature

The South African wine industry is concentrated in the south western and southern parts of the tip of Africa, which is flanked by oceans on three sides. The western coast is bathed by the cold Benguela current while to the south, the warmer Agulhas current is present. The cold water on the western coast contributes to lower rainfall and eventually the desert conditions of the Namib Desert, while along the south and eastern coasts the summer drought of the Mediterranean climate becomes less until it eventually reaches sub-tropical conditions in Mozambique. This strong ocean influence results in summers in the South African winelands being cooler than similar latitudes in the northern hemisphere. The broken relief resulting from the narrow coastal plain, the fold mountains that follow the coastline and the deep narrow valleys result in very varied rainfall. Temperatures also range from moderately cool near the coast and at higher altitudes to very hot in the inland river valleys.

The geological history of the winelands is very ancient, dating back about 1 000 million years. The initial rocks were composed of sediments (schists, shales), which were baked when granite intruded. At a similar time heavy pressure resulted in the formation of mountains. The folded rocks were susceptible to erosion and were leveled. They were once again covered by sediments (sandstones). Again folding of the rocks occurred, followed by erosion. This left a landscape that remains in a similar form today. It has been shaped by the resistance of the rocks to erosion and the important period of the formation of the Cape Fold Mountains.

Soil formation occurred from this parent material during a time when the land went through cycles of being covered by the ocean and subsequently exposed. This together with the complex topography resulted in diverse soils being found within close proximity. Some of the most important soils for viticulture, the deep red or yellow brown structureless soils that are associated with granitic hills or slopes of the mountains, were formed in a period when southern Africa was under a tropical climate. These soils are highly weathered and acid, and are well-drained yet have a good soil water holding capacity. Found in lower positions in the landscape, on the foot slopes of the hills and mountains, are the duplex soils. These soils have a layer of sand over a more clayey layer. On the crests of the undulating hills, one can find residual soils, weathered rock of either granite or shale origin. In the valleys, alluvium of varying nature is present.

An interesting feature of many of the hill or mountain slopes is the "measled" appearance: dark green circles of vegetation amongst the more usual lighter green. These darker circles are due to soil differences, related to ancient termite activity. This activity resulted in soils with a better structure, more optimal pH, better soil water holding capacity and a higher base status. This translates into more vigorous and bigger grapevines in these areas.

The diverse natural environment is reflected in the diversity of the natural vegetation. The wine lands are associated with the renowned Cape Floral kingdom. This kingdom is home to proteas, ericas, daisies, irises, grasses, reeds, pelargoniums and many other plant types. In fact, it contains more than 8 700 plant species, making it the richest plant kingdom, despite being the smallest in surface. Many of these species are very site specific and are only found within a single square kilometre. Because this rich diversity of plant life is a heritage of the diverse climates and soils in the wine growing area, we can expect that these same climates and soils will provide many diverse wine styles.

The beginning

The first person to plant grapevines in South Africa was sent by the Dutch in 1652 to establish a halfway station on the tip of Africa. His name was Jan van Riebeeck. This halfway station was expected to provision the ships of the Dutch East India Company as they rounded the Cape on their journey along the spice route. Being a former ships surgeon, Jan van Riebeeck believed that wine was an important provision to prevent scurvy during long voyages and so he imported grapevines from Europe and planted them in the gardens of the fort in 1655. On 2 February 1659 he is reputed to have written in his diary "Today, praise be to God, wine was pressed from Cape grapes for the first time . . .".

Simon van der Stel, Governor of the Cape Colony from 1659, had an important influence on the small wine industry of the Cape. He was responsible for the import of new cultivars, the encouragement of the settling of French Huguenot refugees and most importantly, the development of a model farm at Constantia, a site ideally suited for the cultivation of grapevines. It was in fact so ideally suited that these Constantia wines gained international acclaim during the late 18th and 19th centuries.

The French Huguenots that were encouraged to immigrate to the Cape Colony also helped to stimulate the industry because of their greater knowledge of wine growing practices. They mainly settled in the areas of Franschhoek

(literally meaning French corner), Stellenbosch and Paarl.

The 18th and 19th centuries held many opportunities, but also challenges for the small South African Wine Industry. The quality of South African wines, with the notable exception of Constantia wines, was not of the highest standard and there was of course resistance on both sides of the export market (Europe and the East). Transport of the wine was a problem due to the distance of South Africa from the market. The wine was not bottled before export but transported in oak vats. As South African oak could not be used to manufacture these vats due to the high porosity of the wood, the vats had to be brought from Europe, often resulting in shortages at the Cape. The vats that were used for wine storage had therefore often been used for other purposes, including brining of meat, and thus did little to enhance the quality of the wines. There was also no protection of geographic indication and unscrupulous merchants used well known names, like Constantia, fraudulently. After the first British occupation of the Cape in the early 19th century, and the subsequent war between France and England, the market for South African wines in the United Kingdom expanded and the young industry grew rapidly. However, peace between Britain and France was resolved and the South African exports collapsed. This was shortly followed by the advent of the phylloxera plague. These factors, together with civil war, wreaked havoc with the wine industry. None the less, mass replanting ensued; resulting in surplus production and exceptionally low prices.

In order to stabilise the industry, cooperative cellars were established, culminating in the establishment of the KWV (Ko-operatiewe Wijnbouers Vereeniging van Zuid Afrika). It had the power to fix quotas and minimum prices and it removed surpluses through distillation and sales on overseas markets. Although this organisation ensured that farm incomes were sustained it had the outcome that innovation was limited.

The wine industry today

Together with many changes on the political scene (release of Nelson Mandela in 1990 and the first democratic elections in 1994) and thus a change in the export opportunities for South African wines, regulation of the industry ceased and quotas were abolished. This led to a period of growth and innovation in the South African wine industry. New regions with the potential to produce high quality wines have been identified and planted to grapevines. New industry players, with a strong spirit of entrepreneurship and ideas for renewal and innovation have emerged. Wine co-operatives are increasingly being converted to companies, and establishing their own marketing and export campaigns. This led to the industry leaders recognising that a vision for the future of the wine industry was needed and Vision 2020 was initiated to propose detailed strategies for the wine industry with the overall aim being "A South African Wine Industry that is innovation driven, market directed, globally competitive and highly profitable, while retaining strong cultural roots, instituting ethical trade practices and meaningful social responsibility programmes, and implementing strategies for affirmative action". This identified a need for a unifying organisation, which was initially named the South African Wine and Brandy Company (SAWB) and has recently been renamed the South African Wine Council. This organisation has a board of directors that represents all stakeholders in the wine industry. There are four business units that are responsible for the roll out of the strategies identified in Vision 2020 and formalised in the Wine Industry Strategic Plan by SAWB, namely a unit for human resource and economic development and empowerment, a unit for generic market development and promotion, a unit for knowledge and information services and inspections and finally a unit for technology innovation and transfer. The Wine Industry Plan is in place to deal with the legacy of a highly regulated economic environment and challenges such as increasing global competitiveness and historical discrimination along racial and gender lines.

The extent of the South African Wine Industry

The South African wine industry represents three categories of products, namely wine (70%), rebate and distilling wine (23%) and non-alcoholic products (7%), and in 2005 accounted for a total production of 8 657 220hl. This production was from a total of 101 607ha of wine grapes with the cultivar spectrum shown in Figure 1.

This cultivar spectrum has changed over the past 10 years with a current focus on premium cultivars. Unplanned, haphazard plantings are a thing of the past with new plantings being based on an inventory of soil types. Based on the soil maps, vineyards are demarcated to ensure homogeneity. Best adapted rootstocks are selected and correct soil preparation techniques are applied. Vine spacing and trellising systems are chosen based on expected vigour. These decisions are aimed at creating vineyards with moderate and homogenous vigour. There is also an increasing focus on the creation of environmentally friendly vineyards under the direction of Integrated Production of Wine (*http://www.ipw.co.za*).

A typical South African vineyard

Soils are subjected to deep delve ploughing with adapted implements and lime, phosphor and potassium are ameliorated before planting. Lime is necessary because many of the soils in the South Western Cape have acidic sub-soils. The main rootstocks used are Richter 99, Richter 110 and 101-14 Mgt. On average 3 435 vines are planted per hectare, dependant on the specific site and cultivar x rootstock characteristics. Most grapevines are vertically shoot positioned, cordon-trained and spur pruned with approximately 16 buds per meter cordon. During summer months, suckering is performed, shoots are positioned and trimmed. Crop control is performed on weak shoots. Many vineyards in South Africa are irrigated. In some instances, where rainfall is usually sufficient, this irrigation is only applied during dry seasons. In other instances, for example in Robertson where the annual rainfall is less than 300mm, full irrigation is applied - often in the form of regulated deficit irrigation.

Some experts of the Demarcation committee investigating a new area for demarcation on the western coast of the Western Cape.

Natural Fynbos

A typical irrigated vineyard in South Africa.

Irrigation is generally applied by means of drip or micro-spray systems. Limited nitrogen fertilisation is applied, and only in situations where leaf and soil analyses and the grapevine vigour indicate that it may be necessary. As clean cultivation is generally practiced, grain is planted in between vineyard rows in the winter and left as a mulch during the summer. The use of permanent cover crops in high vigour situations is however increasing.

The main diseases that have to be dealt with in the vineyards are downy mildew, powdery mildew, boytytis, eutypa lata and leaf roll. Research into the most suitable methods for prevention and treatment of these diseases is current. For downy mildew a disease warning system is in place, which allows for use of systemic agents post-infection. For powdery mildew care, is taken to ensure that disease resistance to Sterol Biosynthesis Inhibitors is prevented. As far as pests are concerned, phylloxera is present in almost all vineyards and grapevines are thus grafted. Planococcus ficus, is considered to be one of the most important pests as it has been identified as a vector for leaf roll transferal between vines and is thus an agent for re-infection of clean plant material with the closterovirus complex. Ants protect Planococcus ficus from its natural enemies (e.g. lady bugs) and thus also need to be controlled. Much research is directed towards the prevention of the spread of leaf roll in vineyards and particularly through control of Planococcus ficus and ants.

Terroirs for South African wines

Initially vineyards were situated close to trading posts and within full view of bays to view approaching ships. The two best examples of these are Constantia, the farm of Simon van der Stel, which is on the slopes of the Constantiaberg, facing towards False Bay, while Vergelegen, the farm of Willem van der Stel (the son of Simon) is situated on the other side of the False Bay. There is in fact a position on this farm, from where it is also possible to see across the Cape Flats to Table Bay. The easy access of Willem van der Stel brought him into conflict with the free farmers of the Cape Colony and he was eventually sent back to Holland as a result of their complaints.

Viticulture did not stay near the coast. As the farmers moved further inland so vineyards were established in valley floor positions, close to available water as irrigation was necessary in these low rainfall areas. More recently research into improved soil and water management technologies has led to vineyard development on slopes. These areas generally have

warmer climates and have been responsible for the production of the majority of fortified wines and rebate wine for brandy production. They currently produce table wines of high quality as a result of improved viticultural and oenological practices.

Since the lifting of the quota system, new zones have been developed at high altitudes and along the coast. These areas have cooler conditions for viticulture and are becoming renowned for their aroma-full white wines.

The wine of origin system

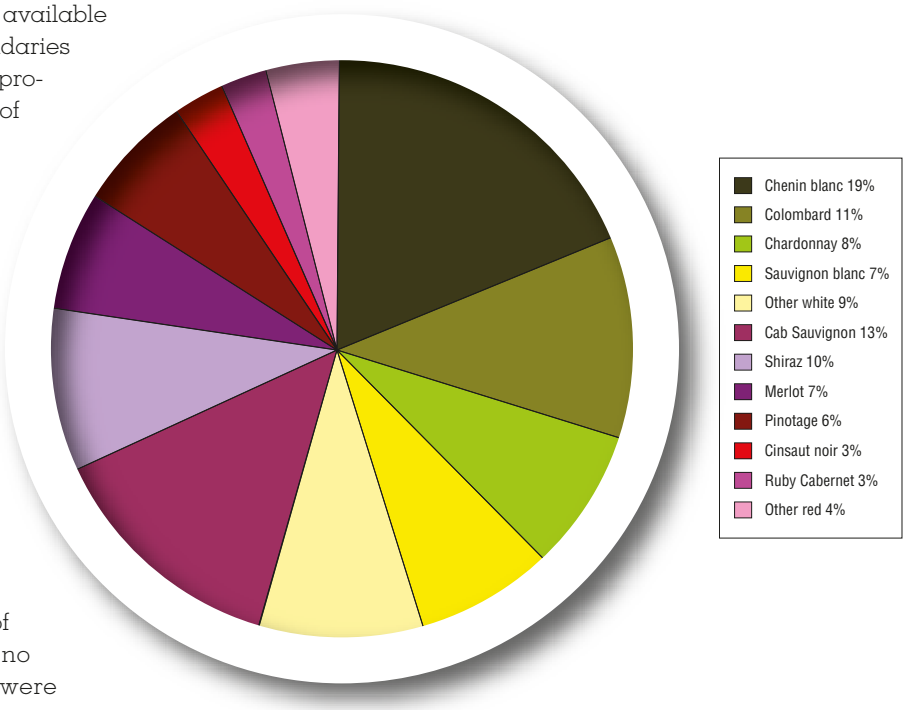
The Wine of Origin scheme was initially legislated in 1973 with the objectives to serve as a basis for the development of distinctiveness and quality of wines; to confirm the correctness of certain indications in connection with the origin of wine and to create confidence in these indications. The importance of origin was seen as residing in the characteristics of soil and climate. Boundaries of areas of origin were therefore compiled based on these characteristics and defined by law. In order to define the boundaries the demarcation committee, consisting of experts in soil science, viticulture and oenology, investigates all available information and recommends the boundaries to the board after consultation with the producers of the area in question. Because of the considered importance of origin, in order for a wine to be certified as a wine of origin, 100% of the grapes must be grown in the demarcated area and it must be made and bottled in this same area. Legislation regarding vintage and cultivar are less strict and only 75% of the wine must be from the stated vintage or cultivar (85% in the case of exports to the EU). A wine will only be certified by the Wine and Spirit Board if all the requirements of the scheme with respect to origin, cultivar and vintage have been met and the wine has been sensorially evaluated by one of the tasting panels of the Board and no unacceptable quality characteristics were found.

The areas of origin are described in a pyramid system (Figure 2). A geographical area is defined by the macro-geographical characteristics related to provincial boundaries (e.g. winter rainfall region of Western Cape). This is the largest area that can be defined. The region is the next largest. It is mainly described by an encompassing area name (e.g. coastal, or the name of a river). A district is defined according to patterns of soil occurrence and macroclimate and must be described by a real geographical place name. Macrogeographical characteristics such as mountains or rivers are often used as boundaries. The most refined delimited area is that of a ward. Here soil, climate and ecological factors are taken into account. The proposed area name has to be a real geographical place name and nature has to dictate that the specific area has the potential to produce wine with distinctive characteristics. Often the areas that are delimited have only recently been planted to vineyards or are at present characterised by few vineyards but have the potential for development. It is a dynamic system with increasingly stringent criteria for demarcation.

Terroir studies in South Africa

Environment has long been recognised as being an important contributor to wine character and quality and in order to assist the demarcation of areas of origin, studies into the effect of environment on viticultural and oenological performance were initiated. The first studies in the early 1970's were focused on the mapping of climate and climatic indices. Simultaneously, investigations into the effect of soil on Cinsaut and Chenin blanc under the same macroclimate were performed.

FIG.1 Cultivar distribution in 2005 taken from the South African Wine Industry statistics no 30 (*www.sawis.co.za*).



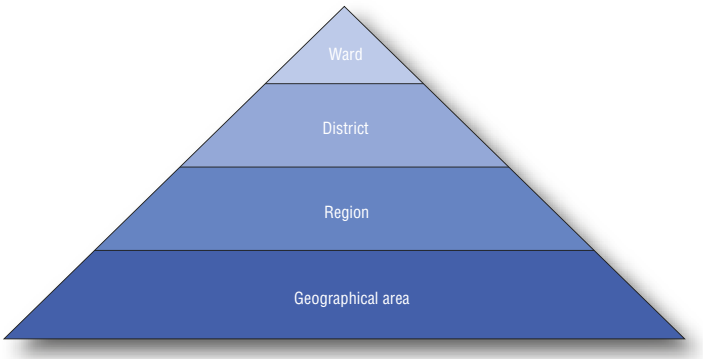


FIG.2 Areas of origin as defined by the South African Wine of Origin Scheme.

Young vineyards against a backdrop of granitic foothills and sandstone fold mountains in the Helderberg Basin, Somerset West, South Africa.

Characteristic yellow-brown to red colours of vineyard soils. These soils generally have good drainage together with good soil water holding properties and after sub-soil compaction and acidity have been alleviated through soil preparation, good root development is obtained.

Viticulture was not the only focus and in order to assist all agriculture, a nationwide survey of natural resources and the mapping of land types commenced in 1971. A land type is "a class of land over which the macroclimate, the terrain form and the soil pattern each displays a marked degree of uniformity" and will differ from another unit in terms of at least one of the following parameters: terrain morphological types, pedosystem, macroclimate or geology. 1:250 000 maps and memoirs for the whole country were completed in the early 21st century. The memoirs contain inter alia descriptions of terrain morphological units and an inventory of the main soil forms to be found on each of these units as well as the principal soil depth and texture per soil type. These land types are often used as a basis for the delimitation of wards of origin.

Although these studies focused on the environment, the first studies under the name of terroir started in 1995. The definition upon which these studies are based describes a viticultural terroir "as a unit of the earth's biosphere that is characterised by relatively homogenous topographical, pedological and climatic features, which find expression through interaction with the vine and vintner, resulting in a distinct wine with an identifiable origin". Terroir studies are grouped under an industry wide research programme with the overarching aim being to integrate all data pertaining to the interaction of different cultivars with their growing environment in a data base and GIS platform in order to be able to formulate a model to serve as a decision aid for site selection. The more general aims of the programme are as follows:

To better understand the terroir/vine/wine interaction for optimal choice of cultivar, vineyard and cellar technology, in order to:

- improve wine typicity and quality and/or
- improve economy of production and/or
- improve sustainability of agricultural practices
- To improve local knowledge with regard to natural resources to aid in terroir demarcation
- To assist a global and national marketing
- campaign for South African wines based

A view from the slopes of the Helderberg, towards Vergelegen and False Bay.

- on the terroir concept and natural
- biodiversity
- To advance the scientific basis for the
- demarcation system
- To add value to the notion of terroir in South Africa

In order to meet these aims, terroir zoning studies have taken place on three levels. At the macro-scale, a study was initiated to identify potential winegrowing areas and to characterise present and potential wine growing areas in terms of their viticultural potential (both yield and wine character) based on environmental attributes. The result was a map of viticultural potential of the Western Cape. This is often used by viticulturists as a first approximation of an area's characteristics and associated viticultural potential. Research is mostly focused at a meso-scale. Preliminary studies into the delimitation of terroir units at the level of a district have been performed for Stellenbosch wine of origin district. Natural terroir units were delimited based on terrain morphological

unit, height above sea level, slope aspect, soil type and geological origin. The degree of influence by the sea breeze was also taken into account. At the same time a network of experimental plots was monitored for a period of seven years and a survey was performed among wine growers in order to determine the response of the grapevine to environmental variables. These data were used to construct decision trees that were applied to the mapped environmental data to delimit terroirs with specific viticultural and oenological potential. Micro-scale studies are generally limited to farm-level consulting services. Geographic Information Systems are used to integrate scientific knowledge, environmental data and mathematical modelling to create maps of relevance for viticulture (e.g. slope, aspect, relief, openness of the landscape, rainfall, soil physical properties, etc). The resulting maps are used for planning decisions for vineyards in order to ensure the best vineyard placement and block design to minimise variability within management units; to choose the optimal row direction, planting density, row width and trellis system; to choose the best cultivar rootstock combination; as a guideline for irrigation designs to ensure water supply to all vines and as a guide to assist in the determination of soil preparation techniques, amelioration requirements and erosion control strategies. These maps are also useful to assist management decisions, such as identifying reasons for heterogeneity in blocks, determining optimal block combinations to obtain the desired wine character and to make long term strategic planning decisions based on the land potential.

Adding value to the concept of terroir

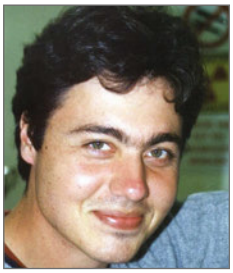
Although research into terroir identification and characterisation was initially driven by research and industry leaders, it appears to now have the general support of the South African wine industry and interest in the concept is growing rapidly. In 2006 two publications were released that reflect this growing interest. The first is a book by Elmari Swart and Izak Smit called "The essential guide to South African Wines: Terroir and travel", which presents the existing wine-producing regions in a system that they call "Wine Pockets". Each Pocket highlights a specific terroir, giving an overview of the characteristics of each wine-producing area, and associates it with wine styles. The second publication is a set of maps of delimited Wine of Origin Districts and Wards published by Wines of South Africa. On the reverse of each map is a table that provides the reader with all the pertinent topographic, climatic, soil and geological information so that the reader can better understand the dominant influences on viticulture in the described area.

Together with the inception of the Wine of origin scheme, wine routes were established in the different wine growing regions. These wine routes are well organised with maps and signboards directing the visitors to cellars that are open to the public for tasting. The characteristic Cape Dutch farm homesteads, with their gabled facades and thatched roofs are often opened as museums or restaurants. These initiatives are expanding and obtaining greater significance in the different wine producing areas.

Finally, the generic marketing campaign by Wines of South Africa for brand South Africa is based on the slogan "Variety is in our nature". This is focused on the rich biodiversity of South Africa, and in particular the fynbos associated with the Western Cape wine producing areas and its relationship to the diverse terroirs that are available for wine production in South Africa, which give rise to unique and individual wines.

Fine tuning grape ripening: Superior wine through genetic control

Mauritz Venter, Department of Genetics, Stellenbosch University



Mauritz Venter

"Times are changing." These words are hard to accept when old and established rules still dominate the winemakers playground. It is all about perception. Even where age-old traditions exist, the unprecedented advance of grapevine biotechnology has yielded a myriad of new biological data and technologies, impossible to ignore. The use of genetic enhancement strategies: to "design" that ultimate cultivar, protected against all the elements, will only take time (and maybe a few "heavy-weights" in the business) for perceptions to change! In this biotech revolution, it may seem that grapevine research has a 'less important' role to play when compared to "hot-shot" science dealing with cancer or stem cells! However, conducting research in a valley where most of the fertile ground harbours a special fruit and trying to discover intricacies regarding all elements responsible for good wine, make grapevine an exciting model to study and manipulate.

Successful genetic manipulation of grapevine requires useful genes to confer specific traits and suitable molecular "switches" known as promoters that control the site and level of gene activity in certain tissues, during different stages of development and/or in response to different elements or conditions. Focussing specifically on promoters, all creatures, plants and organisms have these regulatory elements in their genetic make-up. Every promoter contains a combination of different 'sensors' and these sensors, known as regulatory motifs, are the key players responsible to activate the promoter in response to conditions such as temperature fluctuations, drought stress, ripening signals, pathogen attack, wounding etc. In grapevine, the target-genes regulated by these promoters can be responsible for various cues influencing the quality and stability of good wine. Certain genes have been well characterised and are directly associated with factors such as sugar-acid metabolism, cell wall metabolism, wine aroma as well

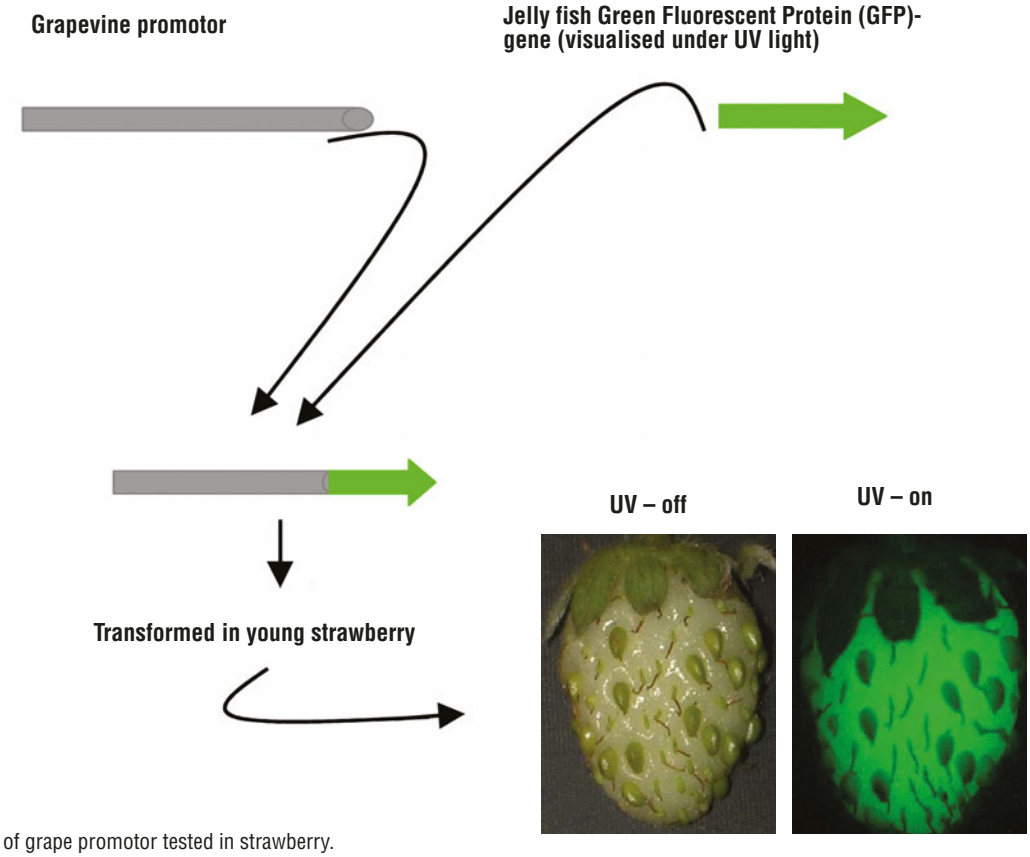


FIG 1: Cut and past of grape promotor tested in strawberry.

as disease and environmental stress tolerance. Analyses of ripening-related genes and the subsequent isolation of promoters in a seasonal crop like grapevine can be a daunting task and therefore, necessitates the implementation of cutting edge research, new technologies and innovative ideas. Scientists today are able to "cut and paste" different segments of DNA to achieve a desired trait. Combined with a well established system to evaluate and use promoter elements in grapevine (and other plants), the possibilities should be endless (Figure 1). However, from theory to practice, promoters implemented to address potential concerns and/or needs that the wine farmer might have, is not so straightforward!

Understanding the complex nature of grapevine molecular biology is of great importance for viticulturists and this is no "pie in the sky" research effort. In theory, this information can be used to design and produce tailor-made promoters for the wine farmer's needs. However, evaluation of "foreign" genetic elements in plants is an expensive and time-consuming process. Therefore, it is necessary to use bioinformatics (where the biologist meets the computer scientist) to formulate putative predictions on how such a molecular switch might behave in the grape berry in response to specific cues. The bioinformatics approach is useful but it is necessary to emphasise that predictions

to understand how a promoter could function must ultimately anticipate experimental confirmation. The combination of promoter and target gene (regulated by that particular promoter) in response to e.g. hormone treatment, different sugars levels, pH fluctuations and/or various stress conditions (heat and cold shock) plays a crucial role in a genetic engineering program.

Realistically, we can only imagine that the use of a genetically modified grape to be used in the production of a very special and expensive bottle of red, will be strangely looked upon by any wine "master" or "connoisseur". The time frame for commercial release of genetically improved grapevine plants is predicted to be between 5 to 10 years. It is realised that due to the long seasonal growth cycle and regeneration time of grapevine during transformation, the evaluation of molecular 'tools' such as promoter elements in stable transformed plants bearing fruit will be time-consuming. That is the nature of applied biological research. However, biotechnology has allowed us to combine modern genetics and conventional breeding strategies to produce a grape berry that could be engineered for stress and disease tolerance. And additionally be improved to potentially meet the exact requirements of the wine farmer regarding elements to make good wine. Therefore, successful genetic improvement and the subsequent commercial release of grapevine will depend on accomplishing a collaborative effort between scientists, wine farmers and a change in public perception.

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Grape ripeness and wine style of Shiraz

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Key words: Shiraz, ripeness, phenolics, tannins, grape composition, wine quality, wine style

Introduction

Initial long-term cultivation choices and technological interventions by growers during the lifespan of a vineyard are steered by wine quality/style requirements, as dictated by the market (Hunter *et al*. 2004) (Fig. 1). The physiological functioning of the vine and the extent to which requirements are met, is an integrated expression of the terroir conditions and cultivation practices (Fig. 2). The vegetative and reproductive growth patterns of the grapevine may have differential and determining effects on grape and wine quality *per se*, but also on the length of the ripening period (harvesting window), thereby impacting on the level of ripeness achieved and the potential for different styles of wine within a particular terroir (Ojeda *et al*. 2002; Hunter *et al*. 2004; Hunter & Deloire 2005).

The uniformity of a vineyard sets the baseline for controlling ripening and harvesting windows for wine styles and will always be displayed in canopy quality (Fig. 3). The key words for judging canopy quality are uniformity, sufficiency and efficiency of both leaf mass and grapes (Fig. 4). A simplified scheme showing the importance of the canopy (*via* photosynthesis and the production of primary compounds) for the formation of various groups of secondary compounds inside the berries, is shown in Fig. 5. The microclimate and composition of the canopy (Fig. 6) are extremely important to increase the output of the canopy (sucrose production, water use efficiency) as a whole and to realise the full potential of the grapes (Figs. 7 & 8) (Hunter *et al*., 2004). The canopy is generally required to continue to satisfy the demands from the ripening berries undergoing physical and biochemical changes during the ripening period (Figs. 9 & 10) (Hunter *et al*., 2004). If this requirement is not met and stress factors (e.g. originating from soil type, soil variation, soil preparation, plant material quality, planting, cultivation practices and/or climate) result in non-uniform growth and premature senescence of the canopy, leading to non-synchronised progressive development of the canopy and grapes, grape composition will be one-dimensional and unbalanced and inferior wine quality will result.

Phenols and related compounds can affect the appearance, taste, mouth feel, flavour and anti-microbial properties of wine. The total berry phenolic concentration slowly increased during ripening, the level of which depended on variety and climatic conditions (Vivas de Gaulejac *et al*. 2001; Habertson & Adams 2002). Tannin concentration mainly decreased during ripening, but on a whole berry basis the tannin content increased at first and stabilised thereafter (Kennedy *et al*. 2001; Ojeda *et al*. 2002; Valls 2004). Bunch and berry characteristics, amount and molecular structure of the phenolics and anthocyanins, must composition, and extraction conditions, affect the concentration and stability of the colour, and the astringency and tannin structure of the wine as well as its ageing potential (Zoecklein 1991; Di Stefano *et al*. 1994; Mazza 1995; Vivas de Gaulejac *et al*. 2001). Wine colour is mainly due to co-pigmentation of

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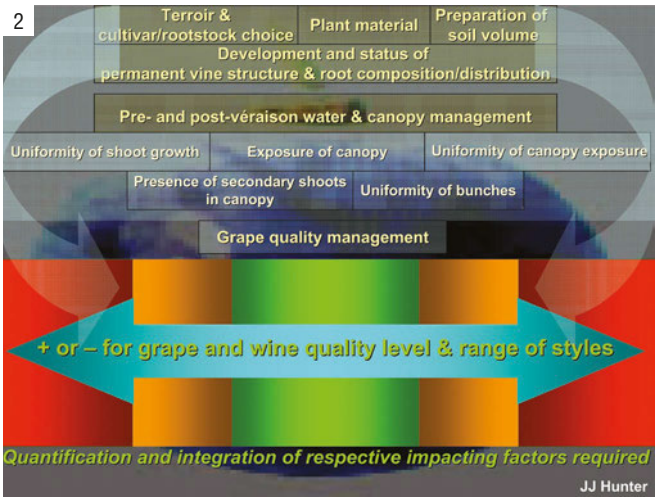

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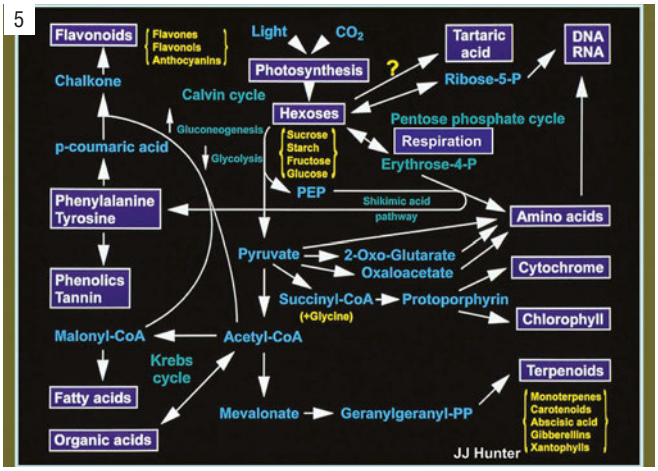

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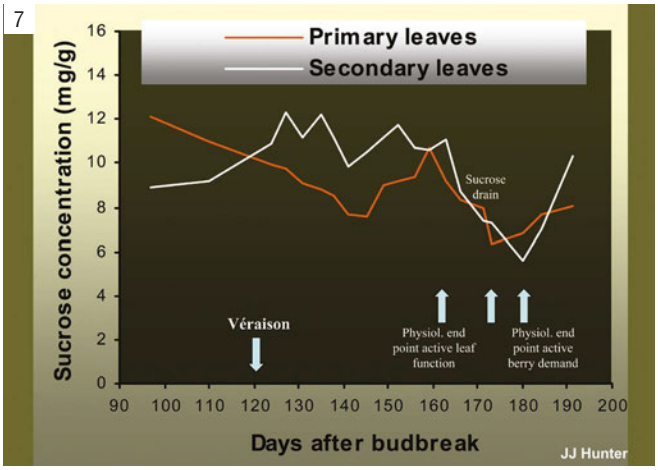

anthocyanins with, among others, catechins and procyanidins, having a stabilising effect on the colour by protecting anthocyanins from oxidation and modification. Longer maceration periods with longer seed and skin contact, pH, SO_2, and ethanol content of the must, as well as temperature and duration of fermentation, may all affect phenol extraction and expression.

Our research was, and still is, aimed at determining grape ripeness levels/ranges for the making of top quality, but different style, wines with unique characteristics; this necessitates the quantification of changes during the grape ripening process and an integration of canopy quality, grape quality, and grape and wine style. Some results from collaborative studies done in South Africa and Spain (Catalonia) are presented. This forms part of a more extensive study (Hunter *et al.*, 2004) as well as other related studies (Hunter & Deloire 2005; Cloete *et al.* 2005; Nadal *et al.* 2005; Pisciotta *et al.* 2005; Deloire & Hunter 2005; Varvaro *et al.* 2005; Deloire *et al.* 2005a; Deloire *et al.* 2005b; Hunter & Deloire 2006; Nadal & Hunter 2007).

Vineyard (South Africa): A seven-year-old Shiraz/R99 vineyard, situated in the Stellenbosch region (South Africa), was used during the 2002 – 2004 growth seasons. Vines are cordon trained (7-wire) and spaced 2.75 x 1.5 m in north-south orientated rows on a medium potential, clayey, Glenrosa soil and a west-facing slope of approximately 26 degrees. Microsprinkler-irrigation was applied at pea berry size and at vèraison stages (12 hours @ 32L/hour). Canopies were vertically trellised, suckered, shoot-positioned and topped, whereas leaves were randomly removed in the lower half of the canopy at two stages, i.e. berry set and pea size (Hunter 2000). Fortnightly sampling was done from berry set up to two weeks post-véraison, after which harvesting for grape analyses, winemaking and wine analyses was done approximately every four days (from 17 February to 24 March), obtaining eight levels of ripeness.

Vineyard (Spain): Shiraz/R110 vineyards, situated in the high humidity, maritime influenced Tarragona (14 years old on a loamy-clay soil) and the dry, low humidity Priorat (18-year-old on a Schist soil) regions were used during the 2004 growth season. Vineyards were non-irrigated, cordon trained and vertically shoot positioned. Berry sampling started two weeks after véraison. Grapes at two levels of ripeness were vinified for each terroir.

Analyses and winemaking (South Africa): Whole berries, skins, seeds, pomace and wine were analysed at each ripeness level. Grapes of all harvests were cooled overnight to 20°C before processing. Grapes were destemmed, crushed and the pomace inoculated with commercial yeast (VIN 13) in 60l tanks. Alcoholic fermentation took place at a controlled temperature of 24°C (di-ammonium phosphate and SO_2 were added). Skins were pushed through three times per day. Fermentation on the skins averaged five days, after which the pomace was pressed. Skins and juice were analysed for anthocyanins, tannins, total phenolics (A_{280}) and colour density ($A_{520 + 420}$) (Ribéreau-Gayon *et al.* 2000) on the first, second and fourth day during fermentation. On the fifth day after crushing (at pressing), seeds were analysed for proanthocyanidins by the DMAC method (that determines catechins and oligomers) (Vivas *et al.* 1994). The same

analysis was performed on the skins and juice (wine). Proanthocyanidin content was also determined in the seeds from intact berries. Total must soluble solids, titratable acidity, and pH were analysed according to standard methods, whereas anthocyanins, tannins and phenolics were analysed in whole berries and wines according to Ribéreau-Gayon *et al*. (2000). The degree of alcohol, total phenolics (A_{280}) and colour density ($A_{520 + 420}$) were also determined in the different wines after bottling.

Analyses and winemaking (Spain): Whole berries, skins and pulp were analysed at each level of ripeness. During the ripening process, berry mass, total must soluble solids, titratable acidity and pH were determined according to standard methods, whereas anthocyanins, tannins and phenolics were analysed in the whole berries (total and extractable anthocyanins) and wines according to Ribéreau-Gayon *et al*. (2000). Grapes were crushed and the pomace inoculated with commercial yeast in 100l tanks. Skins were pushed through twice a day. Alcoholic fermentation on the skins averaged 10 days, after which the pomace was pressed. The degree of alcohol, total phenolics (A_{280}), colour density (A_{520} + A_{420}), proanthocyanidin content (DMAC – Vivas *et al*. 1994), and total anthocyanins, total tannins, and different indexes (HCL index, Ethanol index, Gelatine index – according to Ribéreau-Gayon *et al*. 2000) were determined in the different wines.

Results and Discussion

South Africa

The [0]Balling of the berries reached a high at approximately 11 March (178 days after bud burst), coinciding with the reduction in berry size due to water loss (Fig. 11). The reduction in berry size corresponded with phenol changes in the skins (after 5 days of fermentation), whereas the soluble solid content pattern corresponded to changes in anthocyanin, tannin and total phenolic contents of the whole berry (whole berry extraction) (Fig. 12). Skins lost less colour at the beginning of the maturation period than towards the end. During the last three harvests (after 11 March), extraction of the different phenolic compounds seemed not to be favoured by a higher skin:pulp ratio as a result of the decrease in berry size. Tannins were increasingly extracted from the seeds (values after pressing) with progressive ripening of the berries, coinciding with an increase in the degree of tannin polymerisation and in wine tannin (Fig. 13). This was also clear from the change in wine tannin during fermentation, resulting in two clearly distinguishable groups according to ripeness level of the grapes (Fig. 14). The decrease in phenolic content at the end of fermentation (for all ripeness levels) may be due to different combinations or polymerisations which stabilise the wine and which are not readily analysed (Singleton & Trousdale 1992; Di Stefano *et al*. 1994; Mayen *et al*. 1994). The colour density and total phenolics in the bottled wine clearly corresponded with the trends found when whole berries were extracted, but were opposite to the trends found in skins (Fig. 15). Both berry size and release from skins therefore contributed to wine colour and phenolic content.

Wine tasting showed at least four main wine styles: Style 1: Wines with light colour, herbaceous flavours, high acidity, and astringency with little structure, Style 2: Reasonably balanced wines with less acidity and herbaceous flavour

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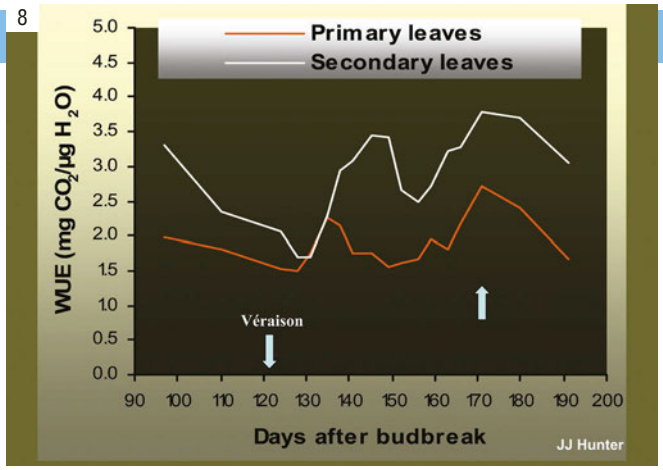

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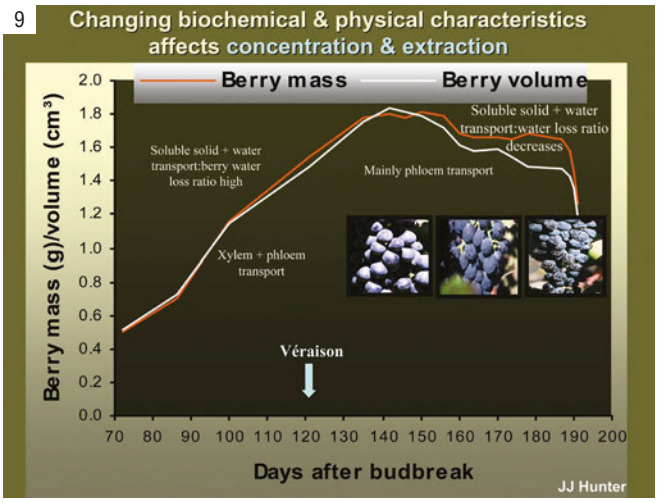

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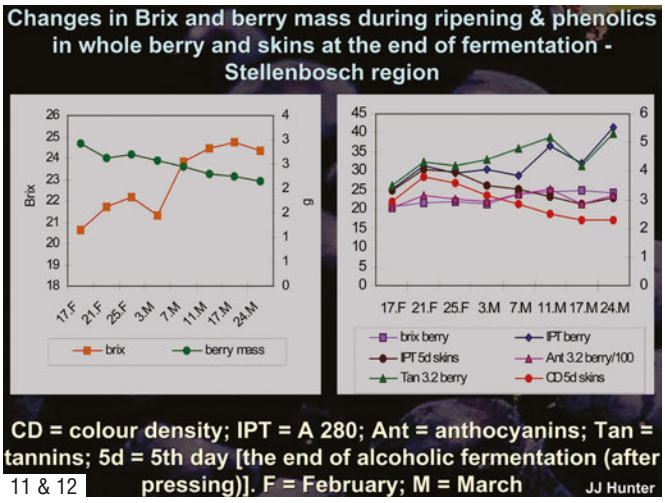

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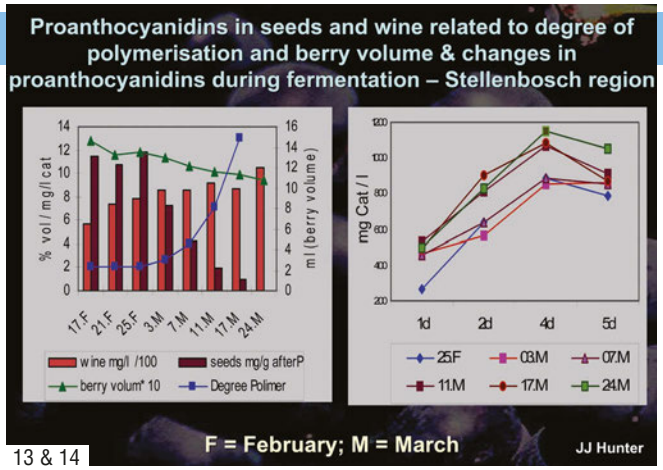

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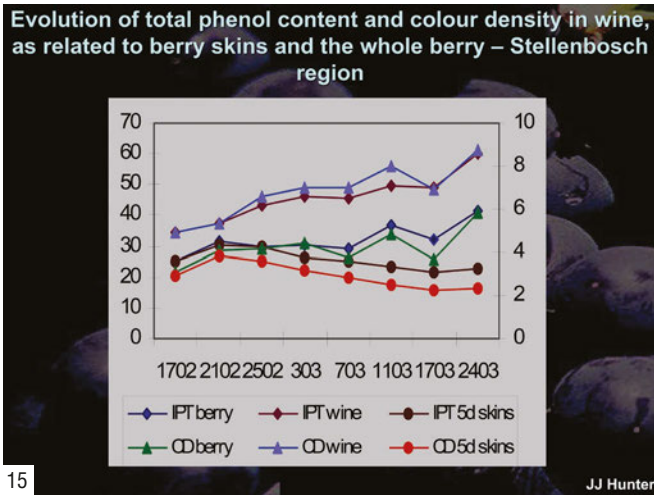
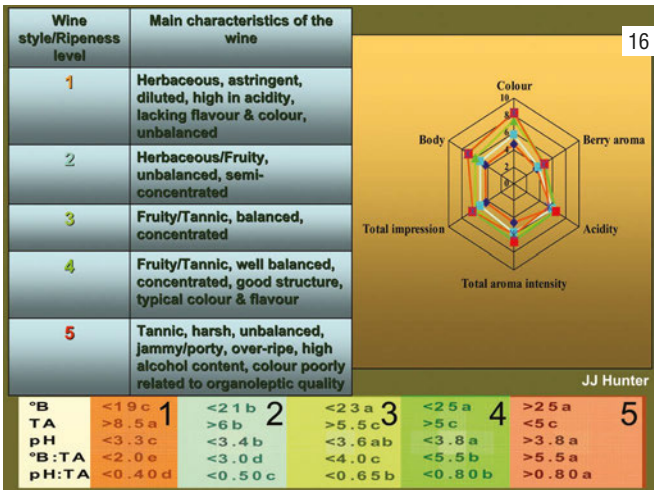
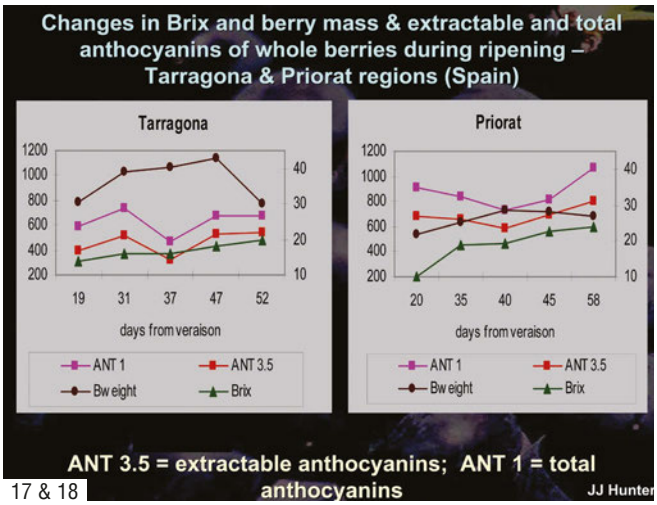


15

Wine style/Ripeness level	Main characteristics of the wine
1	Herbaceous, astringent, diluted, high in acidity, lacking flavour & colour, unbalanced
2	Herbaceous/Fruity, unbalanced, semi-concentrated
3	Fruity/Tannic, balanced, concentrated
4	Fruity/Tannic, well balanced, concentrated, good structure, typical colour & flavour
5	Tannic, harsh, unbalanced, jammy/porty, over-ripe, high alcohol content, colour poorly related to organoleptic quality



	1	2	3	4	5
°B	<19 c	<21 b	<23 a	<25 a	>25 a
TA	>8.5 a	>6 b	>5.5 c	>5 c	<5 c
pH	<3.3 c	<3.4 b	<3.6 ab	<3.8 a	>3.8 a
°B:TA	<2.0 e	<3.0 d	<4.0 c	<5.5 b	>5.5 a
pH:TA	<0.40 d	<0.50 c	<0.65 b	<0.80 b	>0.80 a



17 & 18

and with more colour, fruitiness, body and structure, Style 3: Full-bodied, fruity and complex wines without herbaceousness and with ripe tannins and good colour (comparable to style 4 in Fig. 16), and Style 4: Full-bodied wines which lacked structure and with jammy, over-ripe flavours and harsh tannins (comparable to style 5 in Fig. 16). The Style 3 wines were preferred by the tasting panel. The different styles corresponded to grape composition parameters and ratios determined in a simultaneous study at the time (Hunter *et al.* 2004) and in which five wine styles were evident (Fig. 16). If ratios of ^{0}B:Titratable acidity are considered, these styles would correspond to ratios of <2.0, <3.0, <4.0, <5.5 (preferred) and >5.5 (Fig. 16).

Spain

Similar to results found in South Africa, berry size was reduced during the last stages of the ripening periods in both Priorat and Tarragona (Figs 17 & 18). Growth conditions clearly impacted to a large extent on berry size; the berry sizes reached in the Tarragona region being larger, already at véraison. This also affected the soluble solid concentrations. Lower soluble solid concentrations were reached in grapes of the Tarragona region, despite the ostensible delay in initial soluble solid accumulation in the Priorat region. Given the differences in terroir (Priorat being dry, low humidity climate and vines grown on Schist soils and Tarragona being high humidity, maritime influenced and vines grown on loamy-clay soil), the reaction of the vines in the different regions and the impact on the grapes may have been predicted. In the berries from the Tarragona region, total and extractable anthocyanin contents stayed at the same level during the two harvests (47 & 52 days after véraison), whereas in berries from the Priorat region, anthocyanin contents continued to increase with further ripening (from 45 to 58 days after véraison) and were generally much higher than those found in the Tarragona region. Similar results were found for total phenol contents (data not shown). The higher soluble solid concentrations in grapes from the priorat region resulted in higher wine alcohol contents, whereas the wine colour intensity, and total phenol, tannin monomer, as well as polymerised tannin contents increased (Table 1).

The wine sensorial quality data showed that wines from the second harvests in both regions were more concentrated with less astringency; these wines generally scored higher for all characteristics evaluated (Figs. 19 & 20). Four different styles of wines could be distinguished: Style 1: Wines with low concentration and flavour (Tarragona, Ripeness level 1), Style 2: Wines with reasonable colour and body, but unbalanced because of excessive astringency and a lack of flavour (Tarragona, Ripeness level 2), Style 3: Wines with good balance, colour, concentration and fruitiness (Priorat, Ripeness level 1), and Style 4: Wines with good body, but not well-balanced and with over-ripe characteristics, despite the good colour (Priorat, Ripeness level 2). Wines from the first harvest from the Priorat region were preferred by the tasting panel.

Conclusions

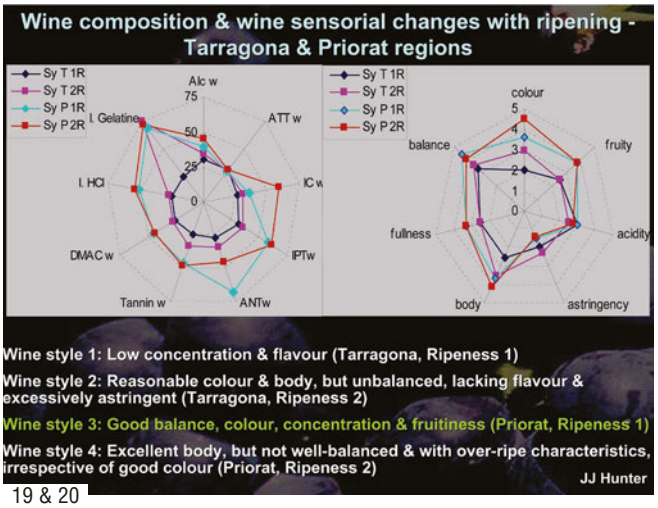
The extraction and concentration of anthocyanins, tannins and total phenolics generally increased with grape ripening. In over-ripe grapes, phenol extraction from the skins seemed limited, despite an increase of values in the wine. However,

Table 1
Wine alcohol & phenolic changes with ripening - Tarragona & Priorat regions

REGION	Alcohol (%)	Colour index	Total phenol index	Polymerised tannin	Tannin monomer (DMAC)
Tarragona 1	10,2	8,8	31	1,22	761
Tarragona 2	11,5	10,5	35,3	1,63	840
Priorat 1	13,2	12,1	58	2,32	1327
Priorat 2	15,0	19,9	61	2,41	1316

JJ Hunter

Table 1



19 & 20

more extraction of flavan-3-ols from the seeds may occur in such grapes, explaining the values obtained in wine. Polymerisation of phenolics in seeds increased according to ripeness level. It can be concluded that the ripeness level of the skins affect the phenol content of the wine and the ripeness level of the seeds affect the nature of phenols in the wine. The results obtained on phenolic patterns during fermentation were matched with wine quality. Corresponding wine styles could easily be differentiated between the various regions. Distinguished wine styles generally ranged from: low-bodied, herbaceous and astringent, unbalanced wines lacking flavour and colour; light style wines, yet fruity and balanced; full-bodied, balanced wines high in fruitiness and tannin structure and typical of Syrah; to high alcohol wines typically showing an unbalanced structure with jammy, over-ripe flavours - in such wines, colour is poorly related to organoleptic quality.

Terroir selection and matching scion-rootstock combination, the quality of graft material, and the choice and execution of long term (soil preparation, spacing, establishment, vine training, trellising and row direction) and seasonal practices (canopy management, fertilisation, water management) are critical in the realisation of the full potential of the terroir-cultivar combination and the impact of the vine on grape composition and chemical and physical balance at the time of harvest. The level of judiciousness in selection and execution will be displayed in the quality of the grapes and wine, the synchronisation of maturation of both canopy and grapes, as well as the variety of wine styles that may be obtained (this also applies to different cultivar clones during initial evaluation for inherent properties). A uniformly growing vineyard that allows the obtainment of a range of wine styles would also increase the possibilities for introducing unique characteristics into a wine by way of blending (from grapes within a vineyard or from cross-blending between vineyards). Wine style refers to a wine with different characteristics that should never be confused with inferior quality. It represents a complex combination of biochemical and physical berry parameters, leading to a unique wine suiting the requirements of a competitive and changing market.

Acknowledgements

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Literature

Cloete, H., Archer, E. & Hunter, J.J. (2005): Shoot heterogeneity effects in a Shiraz/R99 vineyard. Proc. Joint Conference (SASEV, OIV, GESCO) on Viticultural Zoning, 15 – 19 November 2004, Cape Town, South Africa, pp.364 - 371.

Deloire A. & Hunter J.J. (2005): Berry composition as affected by bunch exposure. Progrés Agricole et Viticole 122, 151–157.

Deloire, A., Kraeva, E., Martin, M. & Hunter, J.J. (2005a): Sugar loading and phenolic accumulation as affected by ripeness level of Shyrah/R99 grapes. Proc. GESCO Symposium, 23 – 27 August 2005, Geisenheim, Germany, pp. 574 - 580.

Deloire, A., Zebic, O., Bernard, N., Brenon, E. & Hunter, J.J. (2005b): Influence de l'état hydrique de la vigne sur le style de vin. Revue Francais d'Oenologie 6, 11 - 15.

Di Stefano, R., Borsa, D. & Gentilini, N. (1994): Estrazione degli antociani dalle bucce dell'uva durante la fermentazione; Annuali dell'Istituto Sperimentale per l'Enologia Asti 25, 31-46.

Habertson, F. & Adams, J. A. (2002): Tannins in skins and seeds of Cabernet Sauvignon, Syrah and Pinot noir berries during ripening. Am. J. Enol. Vitic. 53, 54-59.

Hunter, J.J. (2000): Implications of seasonal canopy management and growth compensation in grapevine. S. Afr. J. Enol. Vitic. 21, 81-91.

Hunter, J.J. & Deloire, A. (2005): Relationship between sugar loading and berry size of ripening Syrah/R99 grapes as affected by grapevine water status. Proc. 14th GESCO Symposium, 23 – 27 August, Geisenheim, Germany, pp. 127–133.

Hunter, J.J. & Deloire, A. (2006): Terroir and vine water relation effects on grape ripening and wine quality of Syrah/R99. Proc. VIth International Terroir Congress, 3 – 7 July 2006, Bordeaux and Montpellier, France, pp 110 - 116.

Hunter, J.J., Pisciotta, A., Volschenk, C.G., Archer, E., Novello, V., Kraeva, E., Deloire, A. & Nadal, M. (2004): Role of harvesting time/optimal ripeness in zone/terroir expression. Proc. Joint OIV, GESCO, SASEV Intl Conference on Viticultural Zoning, 15–19 November 2004, Cape Town, South Africa, pp. 466–478.

Kennedy, J.A., Hayasaka, Y., Vidal, S., Waters, E.J. & Jones,

G.P. (2001): Composition of grape skin tannins at different stages of berry development. J. Agricultural & Food Chemistry 49, 5348-5355.

Mayen, E., Merida, J. & Medina, M. (1994): Free anthocyanins and polymer pigments during the fermentation and postfermentation standings of musts of Cabernet Sauvignon and Tempranillo grapes. Am. J. Enol Vitic. 45, 161-165.

Mazza, G. (1995): Anthocyanins in grapes and grape products. Critical reviews in Food Science and Nutrition 35, 341-371.

Nadal, M. & Hunter, J.J. (2007): Different wine styles as related to ripeness level of Syrah/R 99 grapes. Proc. International Intervitis Interfructa Congress, Stuttgart, Germany, pp. 139 - 148.

Nadal, M., Volschenk, C.G. & Hunter, J.J. (2005): Phenolic extraction during fermentation as affected by ripeness level of Syrah/R99 grapes. Proc. Joint Conference (SASEV, OIV, GESCO) on Viticultural Zoning, 15 – 19 November 2004, Cape Town, South Africa, 479 - 487.

Ojeda, H., Andary, C., Kraeva, E., Carbonneau, A. & Deloire, A. (2002): Influence of pre- and postvéraison water deficit on synthesis and concentration of skin phenolic compounds during berry growth of *Vitis vinifera* cv. Shiraz. Am. J. Enol. Vitic. 53, 261–267.

Pisciotta, A., Di Lorenzo, R., Barbagallo, M.G., Volschenk, C.G. & Hunter, J.J. (2005): Shoot positioning: Effect on physiological, vegetative and reproductive parameters. Proc. Joint Conference (SASEV, OIV, GESCO) on Viticultural Zoning, 15 – 19 November 2004, Cape Town, South Africa, 384 - 392.

Ribéreau-Gayon, Y., Glories, Y., Maujean, A. & Dubourdieu, D. (2000): Handbook of Enology, Volume 2: The chemistry of wine and stabilization and treatments. John Wiley & Sons Ltd.

Singleton, V.L & Trousdale, E.K. (1992): Anthocyanin-Tannin interactions explaining differences in polymeric phenols between white and red wines. Am. J. Enol. Vitic. 43, 63-70.

Valls, J. (2004): Composició fenòlica en varietats negres de *Vitis vinifera*. Estudi de la influencia de differents factors. PhD Univ Rovira i Virgili, Tarragona.

Varvaro, G., Nadal, M., López, N. & Hunter, J.J. (2005): Influencia de la maduración y calidad del vino tinto de Syrah. Proc. Gienol Symposium, 3 – 4 June, Palencia, Spain.

Vivas, N., Glories, Y., Lagune L., Saucier C. & Agustin M. (1994): Estimation of the polymerisation level of procyanidins from grapes and wines by use of p-dimethylaminocinnamaldehyde. J. Int. Sci. Vigne Vin 28, 319-336.

Vivas de Gaulejac, N., Nonier, M.F., Guerra, C. & Vivas, N. (2001): Anthocyanin in grape skins during maturation of *Vitis vinifera* L. cv. Cabernet Sauvignon and Merlot noir from Bordeaux terroirs. J. Int. Sci. Vigne Vin 35, 149-156.

Zoecklein, B.W. (1991): An overview of maceration during red winemaking. Austr. & New Zealand Wine Ind. J., 6, 265-267.

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In the cellar

Focus on Rosé

Karien Lourens, Anchor Yeast

Karien Lourens

In recent years there has been an upsurge in interest in rosé throughout the world. Having previously suffered the connotation of being a sweet housewife's wine, sold only in supermarkets, it now features, inter alia, on the wine lists of top Manhattan restaurants, while imports into the British market are increasing steadily. There are several styles of rosé, with the highest demand for dry rosé. Rosé is produced in South Africa under a wide variety of brand names and styles. However, the majority of consumers still believe rosé to be a sweet pink wine costing very little. As a result it does not enjoy the same prestige as Chenin Blanc, Sauvignon Blanc and Chardonnay. A few years ago the perception of "cheap and cheerful" also applied to Chenin Blanc. A few dedicated producers and the Chenin Blanc Association managed to change this perception completely and today Chenin Blanc occupies its place along with Sauvignon Blanc and Chardonnay on shop shelves. The same is currently happening to rosé in the rest of the world and the purpose of this article is to provide local winemakers with guidelines to produce good quality rosé that will not only appeal to the sophisticated wine drinker, but also make South African rosé competitive on the world market.

Why rosé?

There are several good reasons why wine cellars might want to focus on the production of good quality rosé:

- A good dry or off dry rosé is one of the fruitiest and most pleasant wine sensations imaginable. It is simply the perception that all rosés are sweet and intended for housewives and students that prevent more people, especially men, from drinking it.
- Many Pinotage vineyards will produce rosé wines of a quality that is far superior to red wines. This will enable the cultivar to come into its own and Pinotage rosé is not only incredibly fruity, it is also a unique selling point for South Africa.
- Throughout the world there is an enormous red wine surplus. The same consumer who drinks light fruity, dry white wine will also drink light fruity dry rosés and consequently rosé might help to alleviate the surplus.
- South Africa has a fair amount of virus infected red vineyards that struggle to achieve the required sugar for premium red production. These vineyards may be used for the production of good quality low alcohol rosé, rather than attempt the impossible, namely the production of good quality red wine.
- Rosé does not only have to be enjoyed in summer. With good marketing, consumers may be convinced to enjoy a dry rosé with seafood, pasta and antipasta dishes.

Anchor Yeast asked 20 producers of rosé (and Blanc de noir) how they produced their wines. The 20 cellars produce a wide variety of styles at various price points. The following different styles were identified:

- Single cultivar or blend of more than one cultivar, dry
- Single cultivar off dry or semi sweet
- Blend semi sweet and sweet

Category one is the fastest growing market, especially with regard to exports. This category also sells at the highest price points – between R25 and R60 a bottle - and is sold under the producer's premium label. Category 2 fares second best and sales of these wines, on the domestic market especially, are doing well, but not nearly as well as the single cultivar dry rosé abroad. Category 3 does not fare very well, with the exception of one or two brands that are doing well on the domestic market. Among the dry rosés, the more expensive wines under the producers' premium label fare better than wines that are bottled under a cellar's second label and sold at below R25 a bottle. It appears from this preliminary study that there is a growing market in South Africa and abroad for single cultivar, dry rosé with a premium label and in the price category of Chenin Blanc and even Sauvignon Blanc. What follows are a few guidelines from successful rosé producers.

Grapes

There are basically three ways to produce rosé: the "blanc de noir" method which is white wine made from red grapes; the saignée method, whereby juice is separated ("bled off") from red wine fermentations, or by blending white and red wine. Top quality rosé can be produced using the first two methods. Various cultivars are used for the production of rosé, the most popular being Pinotage, Cabernet and Shiraz. The yield per hectare ranges from six to 11 tons, and most of the grapes come from lesser bearing vineyards. It is clear therefore that producers of top quality rosé place just as much emphasis on the quality of the vineyard as the production of top quality red grapes. The law stipulates that it may be blended with up to 15% of another cultivar without stating so on the label. One producer of a Pinotage rosé is of the opinion that 15% Cabernet Franc provides the blend with structure and acid, while the contribution of the Pinotage is mainly that of aroma. Another producer adds 10% Muscat de Frontignan to the Pinotage for additional aroma.

°Balling

This is where vineyards dedicated to rosé production enjoy an advantage over the saignée method. Producers with dedicated vineyards press the red grapes between 21 - 23°B. This results in wines with alcohols between 12 - 13.5%, which is exactly what the average consumer and the export market want. At these sugars red grapes have sufficient flavour and the fact that the grapes are not yet ripe phenolically is not important, seeing that the wine, if made correctly, will contain very few phenolic compounds apart from a few anthocyanins. Producers using the saignée method press any time from 24 - 26°B because it is important for the red grapes to be phenolically ripe for red wine production. Rosés made in this way may therefore be higher in alcohol. This is usually the fuller style compared to the light and fruity style.

pH

pH is extremely important in rosé as it plays an important role in the colour of the wine as well as in the wine's ability to mature. It is important to adjust the

pH before fermentation. Grapes picked at 21 - 23°B may have naturally low pH with good acid, depending on the vintage and the location of the vineyard. Combining this with a lower alcohol will also enhance the light, fruity, crispness and at times mineral style. These rosés usually have the most attractive colour (opinion of the author) i.e. bright pink rather than darker, tending towards red.

Skin contact

There is a great deal of variation with regarding skin contact. The cultivar used will in most instances determine the duration of the skin contact. In general longer skin contact takes place when the sugar of the grapes is lower. In cultivars such as Cabernet Sauvignon, Cabernet franc and Pinotage skin contact is usually very short to avoid too many phenolic compounds. Some cultivars such as Gamay noir and Pinot noir are not very phenolic and skin contact may be longer. Skin contact is a function of cultivar, the ripeness of the grapes, temperature, enzyme dosage and the desired style of the rosé. It is therefore very difficult to give precise guidelines. What is important, however, is that a red colour extraction enzyme should be used, in view of the fact that white enzymes may sometimes entail a side activity of glycosidase. Glycosidase activity has a positive effect on the aroma of white wine, but may have a negative effect on colour, and for that very reason it is also known as anthocyanase. The same applies to the rosé sediment after pressing, although many producers use white sediment enzyme and do not encounter any problems with colour.

Colour

Different markets require different colours. European rosés look like the wines that we have come to know as blanc de noir. The Wine and Spirit Board have specific guidelines for classification of a wine as blanc de noir and as rosé. A wine can therefore be too light or too dark for the Board and consequently not be certified. This leaves little room for the production of "white" Shiraz or Cabernet, an interesting and very successful new concept that has been attempted by a Breedekloof producer. This concept entails the production of a "blanc de noir" without the intention of extracting any colour. The wine will in fact have a tinge of colour - almost like a wine that has undergone pinking, but the target market is the sophisticated wine consumer and the price point of the wine is higher than Sauvignon blanc and Chardonnay and slightly lower than premium red. It is therefore not certain in which category this kind of wine will fall in future if more producers start making it.

One of the ways in which winemakers add colour to their (saignée) rosé is by extending the skin contact. However, if this means that there will be more tannins, they separate the majority of the juice and allow the rest of the juice to ferment a little longer before bleeding off another little bit which is then darker. One producer blends in a certain percentage of thermovinification wine to obtain the correct colour for rosé and others add a little bit of red wine to the final product - less than 15%. One producer does a test of the final colour of the rosé wine by diluting the juice half and half with water in a wine glass. This compensates for the colour that is lost in fermentation. This procedure is used to determine the duration of skin contact.

Yeasts and fermentation temperature

The most commonly used yeast is VIN 13 followed by VIN 7. A few individuals also fermented with CKS 102, K 7, NT 116, QA 23, VL 3 and SC 22. The first six yeasts are able to ferment cold and since rosé juice is handled like white wine after pressing, the winemaker usually opts for cold fermentation with aromatic yeasts. As with white wine production it goes without saying that winemakers will have different preferences for yeasts. The fermentation temperatures range mainly from 13 - 16°C. Rosés can have many different aromas, but by selecting specific yeasts, certain aromas may be enhanced. For example VIN 7 on Cabernet, Merlot and Shiraz is able to emphasise "Sauvignon blanc" type aromas because all three cultivars contain thiols. The strawberry, raspberry, plum and cherry aromas of many red wines and therefore also rosés, are esters and may be enhanced by ester forming yeasts such as VIN 13 and CKS 102. NT 116 may be used on any red grapes except Pinotage. NT 116 forms high concentrations of iso-amyl acetate which has a pleasant smell in all wines except Pinotage, where it may occur in excessively high concentrations. It should preferably not be used for Pinotage rosé therefore. It is used with great success for Pinotage red wine in view of the fact that ester formation is much less at high temperatures.

Stabilisation and filtration

Most producers who have dedicated vineyards for rosé or those who use the saignée method for production find it unnecessary to reduce phenolic compounds with fining agents such as gelatine and egg white. This is because little to no fermentation takes place on the skins. Only the usual protein and tartrate stabilisation take place before bottling. Most producers do sterile filtration even when the wine is dry. A few of the dry Rosé producers only do sheet filtrations.

Cork, synthetic cork, screw cap

At present there are only a few top rosés in screw cap, the reason being that the SA market is not very amenable yet to this type of packaging. Some producers also have special bottles on which the screw cap will not fit. In general the good quality dry rosés have a screw cap or cork. Diam cork is increasingly popular as it cannot possibly get cork faults.

Future of rosé?

Some of the producers who were interviewed are convinced that rosé has a very good future. They have to produce increasing volumes for the US market each year. This market prefers mainly high quality dry, single cultivar rosé. Producers with good domestic sales are those with strong brands and aggressive marketing campaigns.

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Reference:

Jeff Morgan: Rosé, a guide to the world's most versatile wine.

South African wine industry: Personal communications.

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VIN 2000:
A new yeast for the 2008 crush

Karien Lourens, Anchor Yeast

ANCHOR YEAST IS PROUD TO PRESENT A NEW YEAST FOR THE PRODUCTION OF HIGH QUALITY, FULL-BODIED WHITE WINES FOR THE 2008 HARVEST SEASON. VIN 2000, WHICH WAS SELECTED BY THE INSTITUTE FOR WINE BIOTECHNOLOGY, STELLENBOSCH UNIVERSITY, IS PROVISIONALLY RECOMMENDED FOR CHARDONNAY AND CHENIN BLANC.

Origin and evaluation

VIN 2000 was cultivated in 1998 and selected for further research by Prof. Sakkie Pretorius[1] (Institute for Wine Biotechnology, Stellenbosch University) based on the combination of its fermentation abilities and aromatic potential. It was further evaluated by a team led by Dr. Pierre van Rensburg[2], as part of the yeast hybridisation programme at the Institute for Wine Biotechnology. In 2004 Anchor Yeast produced and dried VIN 2000 experimentally and in 2005 and 2006 it was evaluated at the university for small-scale vinification. In January 2007 Anchor Yeast produced VIN 2000 on a large scale and it was tested in the South African wine industry. The conditions under which vinification took place in the South African wine industry presented a very good testing ground for potential new yeasts. High sugars and cold fermentation temperatures usually separated the men from the boys when it comes to yeasts. VIN 2000 passed the test with flying colours and an agreement was reached between the Institute for Wine Biotechnology and Anchor Yeast. As a result it will be available for the southern hemisphere harvest in 2008.

VIN 2000 aroma and flavour

The aroma and flavour of fresh and fruity (new world) wines depend largely on a combination of volatile thiols and esters. Typical esters in wines that were cold fermented (13 – 15°C) with VIN 13 and NT 116, can have banana, pineapple and floral aromas; depending on the yeast used and the grape variety fermented. In Australia and New Zealand the banana-like character, if it occurs in high concentrations, is sometimes referred to as 'confectionary aromas'. The floral esters complement (Weisser) Riesling and Viognier for example. Banana and pineapple esters are suitable for unwooded Chardonnay, but less so for Sauvignon blanc. These types of esters are therefore very desirable for certain wine styles and less so for others. VIN 2000 forms lower concentrations of the 'sweet' type of esters, but higher concentrations of other aromatic esters, and can therefore be used in instances where the 'sweet' type of esters do not suit the wine style or the personal taste of the winemaker (Figure 1). The effect of VIN 2000 on volatile thiols has not been measured, but the wines fermented with it this past season displayed obvious guava, grapefruit and mango aromas and flavours.

VIN 2000 positioning

At present Anchor Yeast has three aromatic white wine yeasts that ferment strongly at cold temperatures, namely VIN 7, VIN 13 and NT 116. Consequently these three yeasts are used mostly for the production of fresh and fruity, tank fermented white wines. However, there is a demand among winemakers for yeasts that complement more full-bodied wines and that ferment more slowly so that they can be used in barrels, for example. The yeasts should therefore ferment more slowly than the three mentioned above, but should be as reliable as VIN 13 and NT 116. Results of the large-scale vinification in 2007 indicate that VIN 2000 complies with these requirements (Table 1).

VIN 2000 is consequently positioned for high quality, full-bodied wines. The vinification techniques accompanying the production of this type of wine are usually slightly higher fermentation temperatures (15-16°C) and oak barrels or oak alternatives. VIN 2000 is provisionally recommended for Chardonnay and Chenin blanc. Results of the trials

TABLE 1: The number of days to completion of fermentation compared to a control yeast on the same juice in commercial fermentations.

CONTROL YEAST	AVERAGE FERMENTATION TEMPERATURE		NUMBER OF DAYS UNTIL DRY	
	CONTROL	VIN 2000	CONTROL	VIN 2000
VIN 7	15.95°C	16.14°C	20	21
VIN 7	14-15°C	14-15°C	12	18
VIN 13	14-15°C	15-16°C	13	15
VIN 13	14°C	14.5°C	14	16
VIN 13	14°C	14-15°C	17	18
VIN 13	14°C	14°C	13	15
Lalvin QA 23*	15.58°C	16°C	10	14
ICV D47*	16°C	16°C	16	16

* Lallemand yeasts

involving the 2007 northern hemisphere crop in France, Spain, Italy and Germany will determine its suitability for other grape varieties.

[1] Sakkie Pretorius is Managing Director at the Australian Wine Research Institute (AWRI).

[2] Pierre van Rensburg is employed by Distell, South Africa.

Contact: Karien Lourens, Anchor Yeast, e-mail: karien@anchor.co.za.

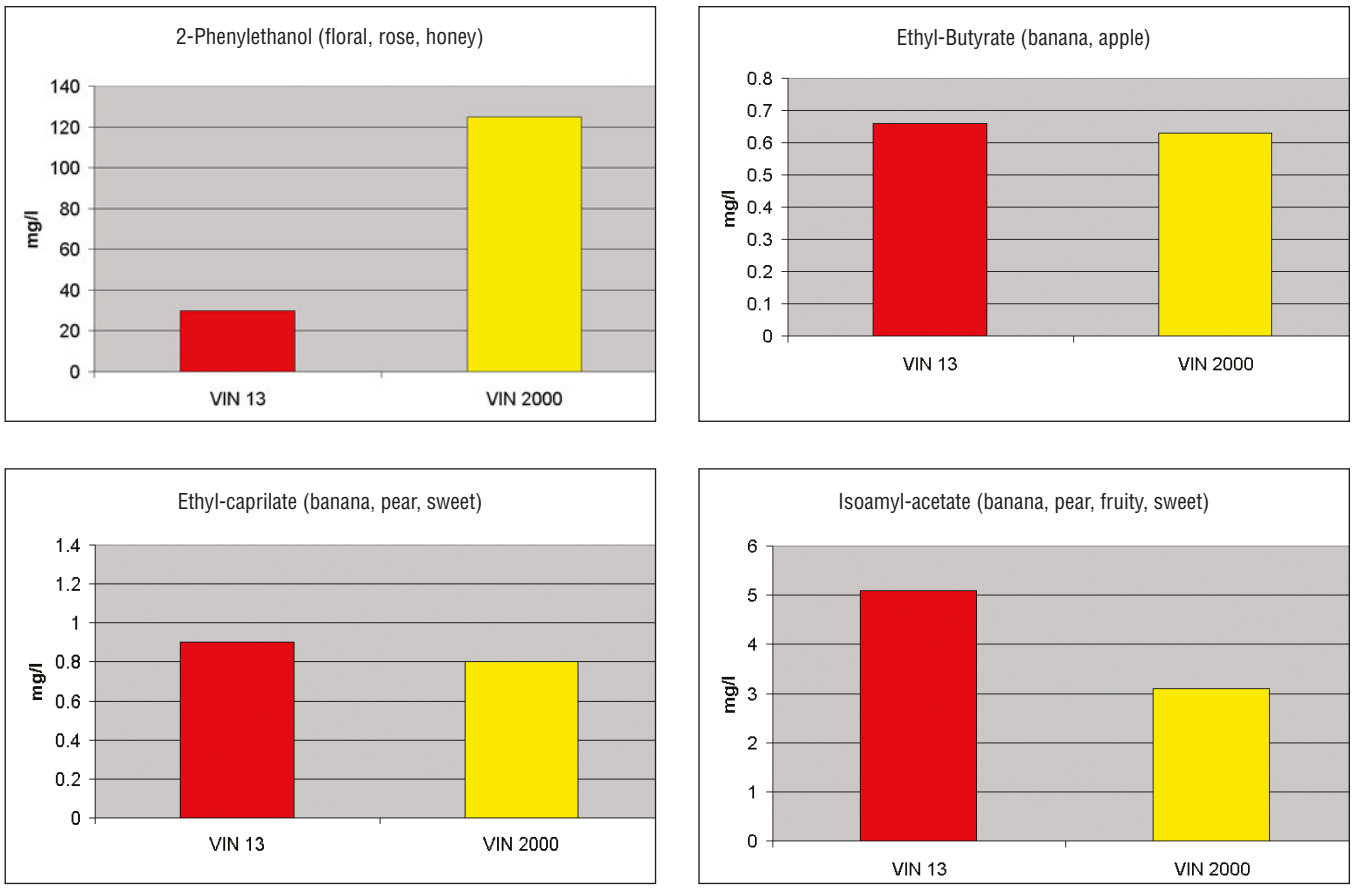

FIG 1: GC analysis on Chenin blanc wine fermented with VIN 2000 and VIN 13, Institute for Wine Biotechnology, Stellenbosch University.

Isolation and evaluation of South African lactic acid bacteria

Heinrich du Plessis, ARC Infruitec-Nietvoorbij, Stellenbosch

Key words: malolactic fermentation, lactic acid bacteria, isolation, evaluation, wine

Heinrich du Plessis

Introduction

Lactic acid bacteria (LAB) play a significant role in winemaking as they are responsible for the secondary fermentation process, namely malolactic fermentation (MLF). Malolactic fermentation is the enzymatic decarboxylation of L-malic acid to L-lactic acid and carbon dioxide (Lonvaud-Funel, 1995). Malolactic fermentation is usually required for the production of red wines and certain white wines such as Chardonnay. However, lactic acid bacteria may also cause spoilage in wine (Fleet, 1993). Lactic acid bacteria occur naturally on grapes and in juice and the effect on wine quality depends on the species and strain, as well as the stage of the winemaking process when MLF occurs (Wibowo et al., 1985; Lonvaud-Funel, 1999). The LAB associated with the vinification process belongs to the genera Lactobacillus, Leuconostoc, Oenococcus and Pediococcus (Lonvaud-Funel, 1999; Du Toit & Pretorius, 2000). Oenococcus oeni (previously known as Leuconostoc oenos) is pH and ethanol tolerant and relatively free of off-odour production, with the result that it is the preferred species for commercial cultures. Lactobacillus plantarum is more sensitive to ethanol and should usually be used before alcoholic fermentation (Henschke, 1993). Other Lactobacillus, as well as Pediococcus species, are usually associated with spoilage (Davis et al., 1985).

The most important reasons for desiring MLF are the contribution it makes to the microbiological stability of wine, production of desirable compounds and the reduction of total acidity (Wibowo et al., 1985). Malolactic fermentations may occur spontaneously as a result of the LAB that occurs naturally, or it may be induced with imported commercial cultures. Although winemakers have relied on spontaneous MLF for many years and usually with good results, the process has obvious risks. If undesirable LAB induce and conduct spontaneous MLF, it may result in the production of off-odours, volatile acids and biogenic amines in wine. The breakdown of arginine by certain LAB may also cause the formation of ethyl carbamate, a potential carcinogen (Du Toit & Pretorius, 2000).

By using commercial cultures to induce MLF, the winemaker has more control over the induction and progress, as well as certainty about the specific LAB that conduct the MLF (Krieger et al., 1990). However, commercial cultures have the disadvantage of being expensive and the success of induced MLF cannot always be guaranteed. There is consequently a need for commercial LAB that is able to conduct MLF quickly and completely under local conditions.

Industry funded research on the factors influencing MLF, as well as problems with the successful induction thereof, has been conducted at ARC Infruitec-Nietvoorbij for the past 10 years (Loubser, 1997, 1999a, 1999b; du Plessis, 2005). The factors influencing MLF have been studied and in the past five years the focus has moved to the characterisation of locally isolated LAB. The purpose of this study was to isolate LAB that occur naturally and evaluate them for use in wine production.

Table 1: Grouping of isolates based on their ability to conduct malolactic fermentation (MLF) in a synthetic medium.

Group	Duration of MLF (days)	Number of isolates
Quick	2 or less	24
Average	3 to 7	58
Slow	8 to 14	26
Very slow	> 14	22

Experimental procedure

Grape, juice and wine samples from different cultivars were collected at various cellars in the Western Cape. Lactic acid bacteria were isolated and characterised. Unless otherwise mentioned, isolates were evaluated in synthetic medium (Capucho & San Romão, 1994) with a pH of 4.5 at 30°C. The isolates were divided into four groups, depending on the time it took to conduct MLF in the synthetic medium, i.e. quick, average, slow and very slow (Table 1). Promising isolates were selected from the group that succeeded in conducting MLF quickly and their ability to conduct MLF at different temperatures and pH was investigated. Lactic acid bacteria were evaluated in duplicate in Merlot and Pinotage wines and commercial LAB served as reference cultures. The analyses before MLF were as follows, Merlot: pH = 3.4, ethanol concentration = 15.3 % (v/v), total SO2 = 30 mg/L, volatile acidity = 0.22 g/L; Pinotage: pH = 3.7, ethanol concentration = 15.7 % (v/v), total SO2 = 30 mg/L and volatile acidity = 0.47 g/L.

Results and discussion

Isolation and characterisation

One hundred and thirty LAB isolates were evaluated for their ability to induce and conduct MLF (Table 1). Forty five per cent of the isolates could be placed in the average group, while only 18% could induce and conduct MLF quickly. Thirteen of the isolates that were able to conduct MLF quickly, were identified as Lb. plantarum, sev-

Table 2: Ability of lactic acid bacteria to conduct malolactic fermentation (MLF) in a synthetic medium at different temperatures and pH.

Lactic acid bacteria	Duration of MLF (days) at temperature			Duration of MLF (days) at pH*	
	15°C	18°C	20°C	3.5	3.0
Viniflora CH35**	6	2	2	5	14
Viniflora oenos**	4	2	2	7	14
Lab 10	6	3	2	6	14
Lab 20	6	3	2	7	14
Lab 30	4	3	2	7	14
102	4	2	2	6	14
107	4	2	2	3	21
128	4	3	1	5	12
144	6	3	1	3	14

*Isolate incubated at 30°C.
**Commercial lactic acid bacteria used as reference cultures.

en as O. oeni and four as Pediococcus species.

Malolactic fermentation in synthetic medium

The ability of promising LAB isolates to conduct MLF at different temperatures and pH is indicated in Table 2. Temperature had a less limiting role than pH on the progress of MLF, but even so influenced the process. Malolactic fermentation took longer at 15°C than at 18°C and 20°C. Most isolates were as effective as the commercial LAB at the different temperatures and pH. Malolactic fermentation took a lot longer at pH 3.0 than pH 3.5 and there were differences between the isolates. Isolate 107 was more pH sensitive and the MLF activity was seriously hampered by a pH of 3.0.

Experimental Merlot wines

The ability of LAB isolates to induce MLF in Merlot wines at different temperatures were investigated (Table 3). Although the isolates completed MLF successfully, obvious differences were noted. The commercial LAB, Viniflora CH 35 and isolate, LAB 30 were the quickest to complete MLF. In most instances malolactic fermentation was quicker at 18°C and 20°C than at 15°C. Noteworthy differences between isolates could be observed at all the temperatures and the differences were biggest at 15°C. These results confirm the temperature sensitivity observed in the synthetic medium. Spontaneous MLF also took much longer than induced MLF. Merlot wines having undergone spontaneous MLF at 15°C, were completed only after 95 days. This is a good indication of the unpredictability of spontaneous MLF.

Table 3: Influence of temperature on the progress of malolactic fermentation (MLF) in Merlot wine.

Lactic acid bacteria	Duration of MLF (days) at temperature		
	15°C	18°C	20°C
Viniflora CH35*	13	13	13
Viniflora oenos*	35	19	20
Lab 10	19	13	13
Lab 20	35	26	21
Lab 30	13	13	13
102	35	20	21
107	42	33	21
128	35	20	13
144	25	20	13
Spontanious AMG	95	49	35

*Commercial lactic acid bacteria used as reference cultures.

Experimental Pinotage wines

The progress of MLF in Pinotage wine is indicated in Table 4. All the isolates, except 144, could conduct MLF successfully. The duration of MLF differed among the isolates, but the differences were not noteworthy. Not one of the isolates produced high levels of volatile acidity and the values are similar to those of commercial LAB. Spontaneous MLF was also not completed after 74 days.

Malolactic fermentation progressed much slower in Pinotage than in Merlot. It is generally accepted that Merlot wines have more difficulty undergoing MLF than other cultivars, therefore MLF should have progressed quicker in Pinotage than in Merlot. However, the trials for the two cultivars occurred over two different years and the slow MLF could possibly be ascribed to seasonal differences.

Promising isolates will be further investigated for the production of undesirable compounds such as biogenic amines and volatile phenols. The best isolates will then be dried and evaluated further.

Conclusion

The LAB isolates that fared best in the induction and progression of MLF in a synthetic medium, were identified as Lb. plantarum, O. oeni and Pediococcus species. All the isolates could conduct MLF in a synthetic medium, but differed in their ability to complete MLF at different temperatures and pH. The

Table 4: Duration and chemical analysis of Pinotage wines after malolactic fermentation (MLF) at 23°C.

Lactic acid bacteria	Duration of MLF (days)	pH	Volatile acid (g/L)	Ethanol % (v/v)	Glycerol (g/L)
Viniflora CH35*	61	3.93	0.56	15.72	13.92
Viniflora oenos*	64	3.95	0.52	15.86	14.02
Lab 10	67	3.95	0.56	15.74	13.75
Lab 20	65	3.99	0.63	15.74	13.85
Lab 30	73	3.96	0.56	15.76	13.82
102	61	3.94	0.58	15.79	13.90
107	61	3.95	0.60	15.80	13.91
128	67	3.95	0.55	15.76	13.87
144	> 74	3.94	0.58	15.79	13.93
Spontaneous MLF	> 74	3.93	0.55	15.84	14.04

*Commercial lactic acid bacteria used as reference cultures.

isolates were able to successfully induce and complete MLF in Merlot and Pinotage wines. Some isolates were more effective than others and fared just as well as the commercial LAB.

Acknowledgements

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References

Capucho, I. & San Romão, M.V., 1994. Effect of ethanol and fatty acids on malolactic activity of Leuconostoc oenos. Applied Microbiology and Biotechnology 42, 391 - 395.

Davis, C.R., Wibowo, D., Eschenbruch, R., Lee, T.H. & Fleet, G.H., 1985. Practical implications of malolactic fermentation: A review. American Journal of Enology and Viticulture 36, 290 - 301.

Du Plessis, H.W. 2005. Appelmelksuurgisting - 'n prioriteit by Nietvoorbij. WineLand, April, 70 - 71.

Du Toit, M. & Pretorius, I.S., 2000. Microbial spoilage and preservation of wine: Using weapons from nature's own arsenal - A review. South African Journal of Enology and Viticulture 21, 74 - 96.

Fleet, G.H., 1993. The micro-organisms of winemaking - Isolation, enumeration and identification. In: Fleet, G.H. (ed.) Wine Microbiology and Biotechnology. Harwood Academic Publishers, Chur. pp. 1 - 25.

Henschke, P.A., 1993. An overview of malolactic fermentation research. Australian and New Zealand Wine Industry Journal 8, 69 - 79.

Krieger, S.A., Hammes, W.P. & Henick-Kling, T., 1990. Management of malolactic fermentation using starter cultures. Vineyard and Winery Management 16, 45 - 50.

Lonvaud-Funel, A., 1995. Microbiology of the malolactic fermentation: Molecular aspects. FEMS Microbiology Letters 126, 209 - 214.

Lonvaud-Funel, A., 1999. Lactic acid bacteria in the quality and depreciation of wine. Antonie van Leeuwenhoek 76, 317 - 331.

Loubser, P.A. 1997. Die werkverrigting van appelmelksuurkulture in Suid-Afrikaanse wyne. Wynboer Tegnies, Mei, T10 - T11.

Loubser, P.A. 1999a. Die interaksie tussen appelmelksuurbakterieë, wyndruifkultivars en Suid-Afrikaanse wyngiste. Wynboer Tegnies, Mei, T48 - T50.

Loubser, P.A. 1999b. Optimum temperatuur - besliste voorvereiste vir suksesvolle appel-melksuurgisting. Wynboer Tegnies, Mei, T56 - T57.

Wibowo, D., Eschenbruch, R., Davis, C.R., Fleet, G.H. & Lee. T.H., 1985. Occurrence and growth of lactic acid bacteria in wine: A review. American Journal of Enology and Viticulture 36, 302 - 313.

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The occurence of apiculate yeasts in grape and must samples from the Robertson area

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Key words: apiculate yeasts, Robertson, wine

Introduction

The predominant non-Saccharomyces yeasts on grapes and in must at the start of fermentation are the apiculate yeasts (Kloeckera apiculata/Hanseniaspora uvarum) (Parish & Caroll, 1985; Bisson & Kunkee, 1991; Frezier & Dubourdieu, 1992; Jackson, 1994; Granchi et al., 1998; Fleet, 2003). These yeasts with their distinctive apiculate or lemon-shaped cell morphology are associated with the production of undesirable volatile acidity. Apiculate yeasts were also isolated by Jolly et al. (2003) during their investigation of grape and must samples from Constantia, Stellenbosch and Slanghoek. However, no apiculate yeasts were found in the Robertson samples during the 1997 and 1998 vintages. During the 2000 vintage apiculate yeasts were isolated, but only 10% of the isolates in the must sample belonged to this group. To elucidate whether the absence and/or low presence of apiculate yeasts in the Robertson samples was specific to the location investigated or was a phenomena of the wider Robertson area, further sites (vineyards) and their corresponding cellars needed to be investigated. The aim of this study was therefore to investigate five vineyard and cellar samples from one vintage for the presence of apiculate yeast.

Areas sampled

Five Chardonnay vineyards (Sites 1 to 5) and their accompanying commercial cellars in the wider Robertson area were selected for sampling. The first vineyard (Site 1) was the same as that sampled by Jolly et al. (2003) while the second vineyard (Site 2) was close (1 km) to Site 1. The other vineyards viz. Sites 3, 4 and 5 were approximately 14, 24 and 28 km from Site 1, respectively (Fig. 1).

Sample collection, isolation and characterisation of yeast isolates

Grapes were randomly and aseptically sampled directly from the vineyard (vineyard sample), one day prior to commercial harvesting, and the corresponding must samples were taken aseptically in the cellar after processing and sedimentation (cellar sample). Yeast isolation was done as reported by Jolly et al. (2003) and a random selection of 30 yeast colonies was made for each vineyard and cellar sample per site. Apiculate yeasts were identified microscopically (400X magnification) and the remaining yeasts were morphologically characterised from colony appearance on YPD agar (Biolab, Merck). The yeasts were subsequently classified as either apiculate, pigmented (orange/red; non-apiculate) and other yeasts (non-pigmented; non-apiculate).

Results and discussion

Sampling sites, yeast isolation and identification

The five sites sampled represent ten sampling points (i.e. five vineyards and five cellars). Although this still does not represent an exhaustive study of the Robertson area, it is more

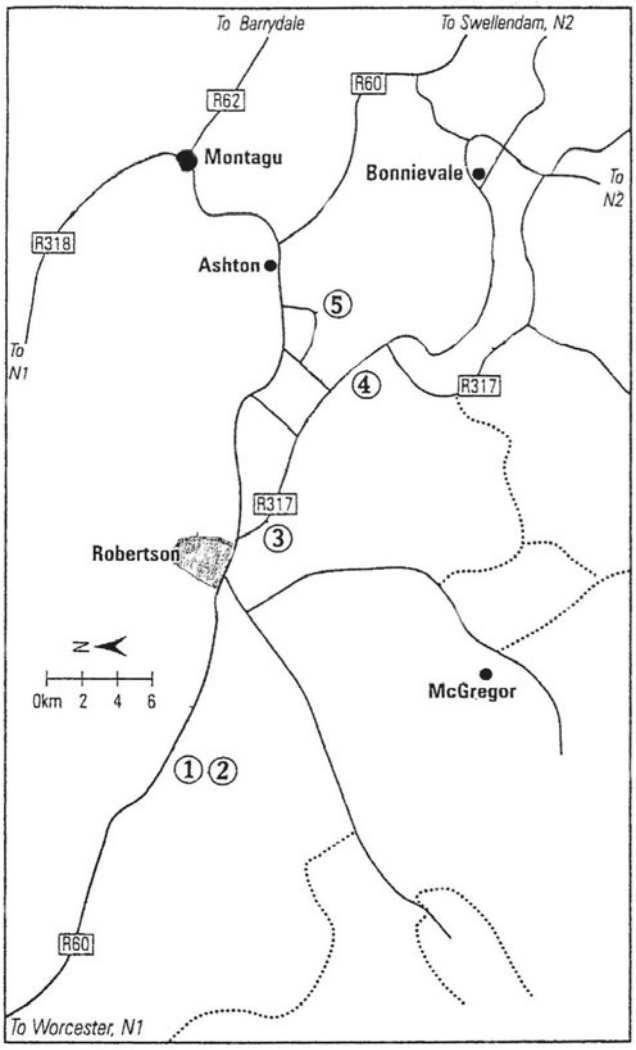

FIG 1: Map of Robertson sampling area indicating positions of sampling sites (numbered 1-5).

representative than the limited previous study (Jolly et al., 2003).

Aseptic sampling of the grapes and the subsequent laboratory procedure avoided contamination of samples by yeasts not present on the grapes. The cellar sample was taken after sedimentation to obtain a representation of vineyard yeasts carried over to the must, as well as yeasts resident on cellar equipment and surfaces that came into contact with the grapes and must during processing, but excluding any yeast that normally would be removed during must clarification.

Random selection of 30 colonies represents from 100% to only 10% of the possible isolates. While it is obvious that some minor species may have been overlooked, the random selection ensured that predominant species were selected. As apiculate yeasts have a distinctive cell morphology, it was easy to distinguish them from the other yeast isolates microscopically. Their colony morphology is also somewhat distinctive (smooth, greyish) and for the purpose of this investigation it was not necessary to do any further biochemical and/or karyotypic identification.

Apiculate yeasts in vineyard and must samples

The apiculate yeasts generally did not predominate in the vineyard samples and were mostly present in low numbers (Table 1). Site 4, the exception, showed in contrast to the other sites, a high percentage (83%) of apiculate yeasts. None of the cellar samples had apiculate yeast predominance. This was against expectations, as there should have been a carryover of yeasts to the must during processing. However, the reduction in numbers of a specific group of yeasts originally present in the vineyard sample has been noted before (Jolly et al., 2003) and can be due to the influences of must clarification techniques and other cellar practices detrimental to yeast growth e.g. addition of SO2. The reduced presence of apiculate yeasts in must samples has also been noted by Yanagida et al. (1992) who used a similar method of yeast isolation as in this study.

The relative close proximity of the vineyards to each other means that they shared similar macro- and meso-climatic conditions so climatic influences on the yeast microflora between the sites should not play a major role. However, individual viticultural practices (affecting the micro-climate) and methods of harvesting (hand vs. mechanical) can vary. This together with cellar practices can impact on the yeast microflora.

It was also evident that with the reduced apiculate yeast presence, the pigmented yeasts e.g. Candida pulcherrima were generally present in higher numbers. This may be due to a number of factors such as pigmented yeasts suppressing the growth of the apiculate or they may be purely opportunistic and filling the "gap" left by the absence of the apiculate yeasts. It has been reported that the pigmented yeast Metschnikowia pulcherrima/Candida pulcherrima has a killer effect against Saccharomyces cerevisiae and some non-Saccharomyces yeasts (Nguyen & Panon, 1998). However, they did not test the effect against apiculate yeasts.

Apiculate yeasts are generally implicated in the production of volatile acidity to the detriment of wine quality (Romano et al., 1992). The absence of apiculate yeasts should therefore imply a smaller risk for winemakers who allow spontaneous fermentation to take place. During this type of fermentation the growth and activity of the indigenous yeasts is not controlled or suppressed by a large inoculum of cultured S. cerevisiae yeasts. Subsequently, the apiculate yeasts, if present, can proliferate, with the concomitant production of volatile acidity. This strengthens the necessity of knowing the non-Saccharomyces species profile and population numbers in a given vineyard and cellar and also the effect these species will have on wine fermentation. Use of this knowledge will enable the wine producer to maximise the desired regional characteristics of his/her wines and minimise any potential spoilage.

One of the cellars investigated in this study (Site 3) makes exclusive use of spontaneous fermentation for their Chardonnay wine, despite the high risk linked to this practice. The results are successful and these wines are sold at premium prices indicating consumer acceptance. Together with this cellar's winning combination of 'terroir', viticultural and oenological practices, the low levels of apiculate yeasts in

TABLE 1: Occurence of apiculate in Chardonnay vineyard and cellar samples from the Robertson area.

Yeast type	% Isolates at sampling points									
	Site 1[1]		Site 2[1]		Site 3		Site 4		Sit 5	
	Vineyard sample	Cellar sample	Vineyard sample	Cellar sample	Vineyard sample	Cellar sample	Vineyard sample	Cellar sample	Vineyard sample	Cellar sample
Apiculate yeasts[2]	0	10	13	0	7	0	83	7	30	7
Pigmented yeasts[3]	47	17	37	23	20	20	0	3	3	0
Other yeasts	53	73	50	77	73	74	17	90	67	93

[1] **Sites 1 and 2 share the same cellar.**

[2] **Apiculate yeasts. *Kloeckera apiculata* and *Hanseniaspora uvarum*.**

[3] **Pigmented yeasts eg. *Candida pulcherrima* and *Rhodotorula* spp.**

the Robertson area can be contributing to their success. The belief of the old world wine producers concerning indigenous yeast contribution to the regional characteristics and quality of wines (Amerine et al., 1972; Jackson, 1994) seems to be substantiated in this case.

Conclusions

This study achieved its purpose of elucidating the occurrence of apiculate yeasts in the broader Robertson region. These yeasts are generally not predominant in the Robertson area and this could have a positive impact on the quality and regional characteristics of the wine produced there, especially if spontaneous fermentation practices are followed.

Literature cited

Amerine, M.A., Berg, H.W. & Cruess, W.V, 1972. The technology of winemaking. The AVI Publishing Company, Inc., Connecticut.

Bisson, L.F. & Kunkee, R.E., 1991. Microbial interactions during wine production. In: Zeikus, J.G. & Johnson, E.A. (eds). Mixed cultures in biotechnology, McGraw-Hill, Inc., New York. pp 39-68.

Fleet, G.H., 2003. Yeast interactions and wine flavour (review article). Int. J. Food. Microbiol. 86, 11-22.

Frezier, V. & Dubourdieu, D., 1992. Ecology of yeast strain Saccharomyces cerevisiae during spontaneous fermentation in a Bordeaux winery. Am. J. Enol. Vitic. 43, 375-380.

Granchi, L., Ganucci, D., Messini, A., Rosellini, D. & Vicenzini, M., 1998. Dynamics of yeast populations during the early stages of natural fermentations for the production of Brunello de Montalcino wines. Food Technol. Biotechnol. 36, 313-318.

Jackson, R.S., 1994. Wine Science - principles and applications. Academic Press, San Diego.

Jolly, N.P., Augustyn, O.P.H. & Pretorius, I.S., 2003. The occurrence of non-Saccharomyces yeast strains in four vineyards and grape musts in four production regions of the Western Cape, South Africa. S. Afr. J. Enol. Vitic. 24, 35-42.

Nguyen, H.-V. & Panon, G., 1998. The yeast Metschnikowia pulcherrima has an inhibitory effect against various yeast species. Sci. Aliments. 18, 515-520.

Parish, M.E. & Caroll, D.E., 1985. Indigenous yeasts associated with Muscadine (Vitis rotundifolia) grapes and musts. Am. J. Enol. Vitic. 36, 165-169.

Romano, P., Suzzi, G., Comi, G. & Zironi, R., 1992. Higher alcohol and acetic acid production by apiculate wine yeasts. J. Appl. Bact. 73, 126-130.

Yanagida, F., Ichinose, F., Shinohara, T. & Goto, S., 1992. Distribution of wild yeasts in the white grape varieties at central Japan. J. Gen. Appl. Microbiol. 38, 501-504.

Aroma profiles of South African Wines

The ability to guarantee authenticity and detect fraud in foods and beverages is becoming increasingly important internationally. In the case of wine, the ability to detect possible addition of aroma constituents to wine can only be based on an extensive knowledge of what naturally occurs in wine. The Wine Industry (Winetech) regarded this matter of extreme importance, and therefore called for a research project on the aroma profiles of a number of cultivar wines. The project commenced in 2005 and will probably be completed in 2008.

At present, different research institutions (ARC Infruitec-Nietvoorbij, University of Stellenbosch and University of Cape Town) collaborate in conducting this project. The aim of the project is to compile comprehensive databases ("fingerprints") on aroma components in wines of the most important South African cultivars, originating from the various geographical regions. Unwooded, young wines of six cultivars (Cabernet Sauvignon, Merlot, Shiraz, Pinotage, Chardonnay and Sauvignon blanc) are sampled annually from the Young Wine Show, as well as from origins not represented at this show. The wines of each cultivar are selected according to their regional distribution, and are therefore representative of the South African wine industry. The samples are 100% cultivar wines. About 70 to 100 samples per cultivar per season are collected.

Wine contains hundreds of volatile constituents some of which have no impact on aroma, some which only contribute to the general wine-like background, while others directly impact on aroma. Wine aroma components represent a variety of chemical classes and are present in widely divergent concentration ranges. The most important aroma groups in wine are: esters, higher alcohols, lactones, monoterpenes, norisoprenoids, methoxypyrazines, mercaptans, volatile phenols and wood-derived components. Because most impact aroma components are extremely aroma effective (low threshold values), very small amounts can have a major effect on wine characteristics. Fraud detection is based on deviations from levels of naturally-occurring impact compounds, and variations in the general profile or ratios between components, or both.

In addition, the composition of relevant commercial flavour essences and plant extracts are examined to supply support data. The results of this research will assist authorities in future to detect fraud.

Naturally, it is impossible to analyse all the relevant components in a single standard analysis. Therefore different methods are used, namely:

- Liquid/liquid extraction of volatiles using diethyl ether (GC-FID). This method gives a general wine aroma profile for all six cultivars (Managed by the University of Stellenbosch. Project Leader: Prof. P van Rensburg).
- Headspace extraction of volatiles (Solid Phase Micro Extraction). This method gives a general aroma profile of the headspace of wine for all six cultivars (Managed by the ARC Infruitec-Nietvoorbij. Project Leader: Dr. O. Augustyn).
- Headspace extraction of methoxypyrazines (Solid Phase Micro Extraction). This method gives a specific methoxypyrazine profile for Sauvignon blanc, Cabernet Sauvignon and Merlot (Managed by the ARC Infruitec-Nietvoorbij. Project Leader: Dr. I. Burger).
- Liquid/liquid extraction of mercaptans. This method gives a specific mercaptan profile for Sauvignon blanc, Cabernet Sauvignon and Merlot (Managed by the University of Cape Town. Project Leader: Prof. S. Burton).
- Headspace stir bar extraction followed by thermal desorption (HSSE-TD-GC-MS). This method gives a general aroma profile of the headspace and/or liquid phase for all six cultivars (Managed by the University of Stellenbosch. Project Leader: Prof. A. Crouch).

Dr. Johann Marais is the coordinator of this project

Project leaders from left: Dr Johann Marais (project co-ordinator), Jan Booysen (executive manager Winetech), Prof Pierre van Rensburg (University of Stellenbosch), Prof Stephanie Burton (University of Cape Town), Dr Irmi Burger (ARC Infruitec-Nietvoorbij), Prof Andrew Crouch (University of Stellenbosch) en Dr Ockert Augustyn (ARC Infruitec-Nietvoorbij).

Micro-oxygenation in South-African wine: Part I

Wessel du Toit, Department of Viticulture and Oenology, Stellenbosch University

Wessel du Toit

Micro-oxygenation is receiving more attention today. The following article will deal with some practical aspects regarding micro-oxygenation, as well as the effect it has on the phenolic composition of wine. The second article will focus on the effect it has on the microbial population, sulphur compounds, SO_2 levels, micro-oxygenation in combination with oak wood and its effect on the taste of wine. Some general recommendations will also be given. During micro-oxygenation small, controlled amounts of oxygen (O_2) are bubbled into wine to bring about positive changes in the wine. This is achieved by filling a known volume with gas at a high pressure. The volume is then transferred via a low-pressure circuit to the diffuser and into the wine. The latter normally consists of a ceramic or stainless steel sparger that produces small bubbles, which can dissolve in the wine. The aim of micro-oxygenation is to introduce O_2 into the wine at a rate equal to or slightly less than the wine's ability to consume that O_2 to avoid too much O_2 build up in the wine. It has to be managed in such a way that, after addition, all O_2 has been used up, while sufficient SO_2 is still left to protect the wine against excessive oxidation and microbial spoilage. These changes include the following (some of them claimed by the producers):

- Supply yeast with O_2 during fermentation to assist with the production of sterols and other fatty acids
- Enhance colour in red wine
- Enhance colour stabilisation
- Remove unwanted reductive flavours
- Speed up the aging process of red wine
- Simulate an oak barrel to a certain degree

A few practical recommendations

How is micro-oxygenation brought about? The equipment entails using a gas canister which contains oxygen, linked to a special micro-oxygenation machine which can dose the O_2 accurately. Different machines exist on the market. Some can dose in mL/L while others dose in mg/L. From the dosing machine a small pipe bubbles the O_2 in a fine bubble form into the wine from the bottom of a tank. The sparger used for this can either be made from stainless steel or ceramic. The latter is reputed to lead to smaller bubbles, which can dissolve better in the wine, but stainless steel is obviously more robust. The tank also needs to be at least 2.5 m tall to facilitate dissolving of the bubbles in the wine. When micro-oxygenation is applied care should be taken that the bubbles dissolve in the wine and does not simply move to the top of the tank. The pressure from the gas canister to the dosing machine should also be monitored regularly. The sparger should be cleaned after a wine has been treated, by leaving it in a caustic solution for a few hours and then rinsing it thoroughly with clean water. Also make ensure that the pipe leading from the dosage machine to the sparger is free of liquid.

Oxygen can be supplied during different stages of the winemaking process. It can be supplied at 1-5 mg/L/day for a few days just after malolactic fermentation, especially to press wine fractions that are rich in polyphenols. The stage

Table 1: Different commercial wines with their origins and treatments.

No	Cultivar and year	Origin of wine	Treatment
A	Cabernet Sauvignon 2002	Paarl	0, 1.5 and 3 mg O_2/L/month with oak slaves starting just after the completion of malolactic fermentation.
B	Red blend 2003	Stellenbosch	0 and 4 mg O_2/L/month with oak staves starting just after the completion of malolactic fermentation.
C	Pinotage 2004	Paarl	0, 1.5 and 3 mg O_2/L/month with oak staves starting seven months after the completion of malolactic fermentation. The same wine was also matured in an oak barrel of the same wood as the staves used (USA MT+).
D	Shiraz 2003	Worcester	0 and 3 mg O2/L/month with oak staves starting seven months after the completion of malolactic fermentation.

Table 2: Concentrations of different phenolic compounds in wine C initially and after 24 weeks treatment.

Compound	Initially	Concentration (mg/L) for each treatment			
		Control	1.5 mg O_2/L/month	3 mg O_2/L/month	Barrel
Gallic acid	46.4	56.1	50.3	57.2	47.3
Gentisic acid	1.5	2.6	nd	1.5	nd
Caftaric acid	17.3	16.3	17.5	16.8	17.3
Vanillic acid	2.6	4.1	5.1	3.3	43.7
Catechin	790.2	784.0	704.4	698.6	659.5
Caffeic acid	64.2	59.0	56.8	57.0	52.6
Procyanidin B1	60.0	91.0	93.5	55.6	78.5
p-Coumaric acid	3.6	3.8	4.2	6.4	12.2
Procyanidin B2	49.1	40.8	40.4	40.0	39.8
Epicatechin	90.1	73.6	76.2	68.8	80.5
Delphinidin-3-glucoside	11.2	7.7	7.4	9.6	7.2
Petunidin-3-glucoside	13.8	7.6	9.3	8.5	8.7
Peonidin-3-glucoside	5.5	2.9	4.1	3.4	4.1
Malvidien-3-glucoside	117.9	63.4	83.8	72.0	79.6
Ellag acid	3.7	4.8	4.5	5.4	3.3
Quercetin-3-glucoside	15.8	12.3	13.6	11.1	14.7
Myricetin	4.3	3.2	5.1	5.1	4.3
Quercetin-3-rhamnoside	5.0	4.2	3.4	4.7	4.0
Malvidin-3-Acetate	40.1	18.4	23.8	24.2	22.4
Quercitin	7.8	4.8	6.4	5.8	5.2
Malvidin-3-p-coumaric acid	19.6	6.8	11.1	9.6	10.0
Polymeric pigment	28.8	29.0	33.9	34.8	35.3
Polymeric phenols	791.6	782.9	947.1	1021.5	1132.0

when micro-oxygenation is normally applied is during the ageing period after malolactic fermentation, when between 1-6 mg/L/month is introduced into the wine, although certain researchers recommended adding even up 10 mg/L/month. The wine's temperature must be around 15°C because temperatures that are too high will lead to poor solubility of O_2 and temperatures that are too low to chemical reactions taking place too slowly.

One of the main aims of micro-oxygenation is to bring about changes in the colour and phenolic composition of wine. It is well known that the addition of O_2 to wine leads to polymerization of certain phenolic compounds, such anthocyanin and flavanol moieties (catechin and condensed tannins). This polymerization occurs due to the formation of $H2O_2$ from the oxidation of a phenolic molecule. $H2O_2$, being a strong oxidant, oxidizes ethanol, which yields acetaldehyde. The latter forms a bridge between phenolic molecules, leading to the polymerization. Just after fermentation a large percentage of anthocyanins are still in the colourless form. Slight oxidation, as would happen with a racking of wine, leads to these colourless anthocyanin molecules binding to tannins and changing into red or brown red compounds. When red wine is matured in oak barrels O2 also comes in contact with the wine, but this does not happen when it's matured in stainless steel tanks, without O2 addition such as micro-oxygenation.

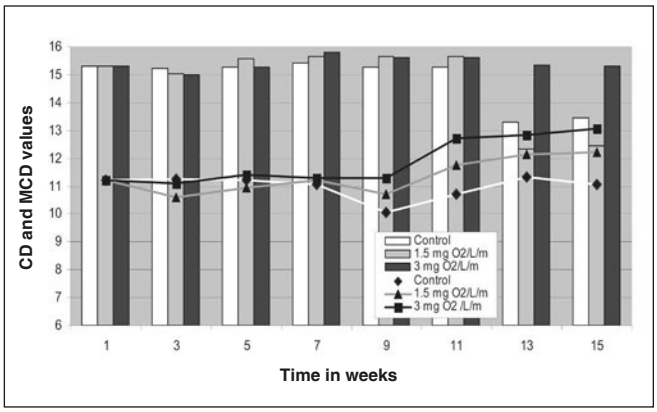

FIG 1: Colour (CD) (lines) and modified colour (bars) density (MCD) of wine A during micro-oxygenation treatment.

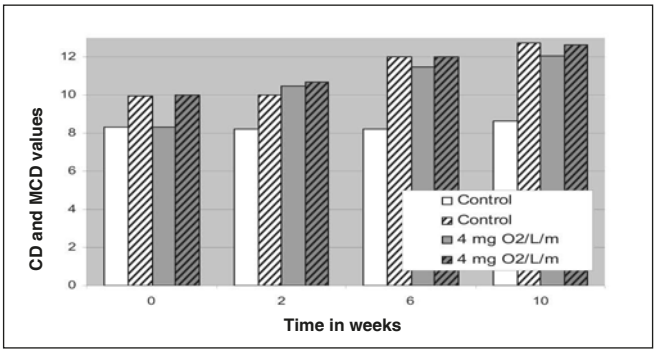

FIG 2: Colour (CD) and modified colour density (MCD) of wine B during micro-oxygenation treatment.

Experimental observations

We decided to investigate the effect of micro-oxygenation on different South African red wines.

Materials and methods

Four different SA red wines were monitored in terms of their phenolic and colour development during micro-oxygenation (Table 1). Note that in wines A and B the treatment started just after malolactic fermentation and wines C and D seven months after malolactic fermentation. Different spectrophotometric analyses were conducted during the course of the experiments. These included wine colour density, modified wine colour density (the modified version of the analysis negates the effect of pH and SO_2 on the analysis), wine colour hue, total red pigments, total phenolics and estimate of SO_2 resistant pigments. The fractions of co-pigmented anthocyanin, free anthocyanins and polymeric colour pigment content in the red wines were also determined. The estimate of SO_2 resistant pigments and modified colour density were used to analyse these fractions. Total anthocyanin concentrations, total tannin concentrations, HCl index value (index of polymerisation of procyanidins) and gelatin index values (index of reactivity of phenolic molecules in wine towards gelatin) were also conducted. Additional phenolic analyse were performed with HPLC.

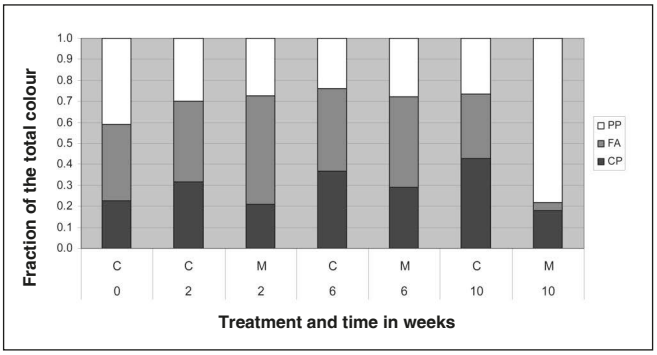

FIG 3: Development of the fraction of colour of wine B during micro-oxygenation treatment c: control tank, M: micro-oxygenation tank receiving 3mg O2/L/month. PP: Fraction of colour due to polymeric fraction, FA: Fraction of colour due to free anthocyanins, CP: Fraction of colour due to co-pigmentation.

Results

It is clear from Fig 1 that the colour density of wine A increased with increasing concentrations of O_2 added. In wine A, micro-oxygenation led to a decrease in total phenolic concentrations (which was high in this wine) after seven to nine weeks and were lower in the treated wines after 15 weeks (results not shown). The colour pigment in this wine also increased with O_2 addition. The free anthocyanin fraction was also smaller in the treated wines (results not shown), as well as the difference between the colour density and modified colour densities. The latter shows that the colour became more resistant towards the bleaching effect of SO_2. This indicated that more free anthocyanins were incorporated into polymeric pigment form, leading to the increase in colour.

The same trend happened in wine B (Fig 2) where the micro-oxygenation led to a drastic increase in the colour density (which could be observed with the naked eye), but not the modified colour densities (where the bleaching effect of SO_2 is negated). The fraction of colour in the polymeric pigments was much higher than that of the control wine (Fig 3).

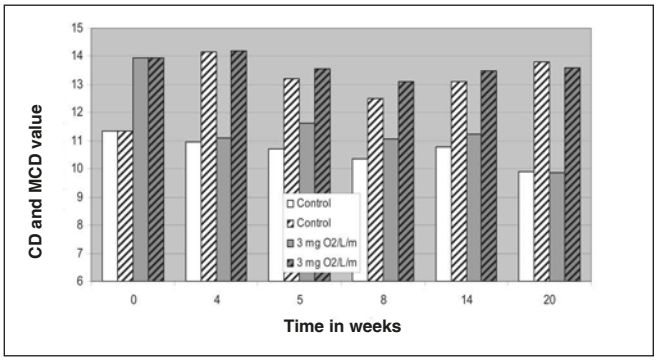

FIG 4: Colour (open bars) and modified (striped bars) colour density of wine D during micro-oxygenation treatment.

However, the addition of O_2 with micro-oxygenation does not always lead to drastic increases in colour density. This was true for wines C and D (Fig. 4). Micro-oxygenation, if used to increase the colour of red wine, would rather be used just after malolactic fermentation, where a large part of the anthocyanins are still in the colourless form. New research also showed that the addition of O2 between alcoholic fermentation and malolactic fermentation also lead to less colour being lost during malolactic fermentation. Total red pigments decreased, as would happen when red wine is aged in a barrel in all the treatments, but were slightly higher in the treated wines after 15-18 weeks than in the control (Fig. 5).

The HPLC results for wine C can be seen in Table 4.3. Vanillic acid was much higher in the barrel treated wine than in the other treatments, probably due to the higher oak contact. Catechin and procyanidin B1 concentrations decreased with the increasing O_2 addition over time, with the malvidin-3-glucoside concentration being lower in the control wine. The procyanidin B1 concentration can also increase over time due to catechin associations, explaining the higher concentrations in the control wine after 24 weeks.

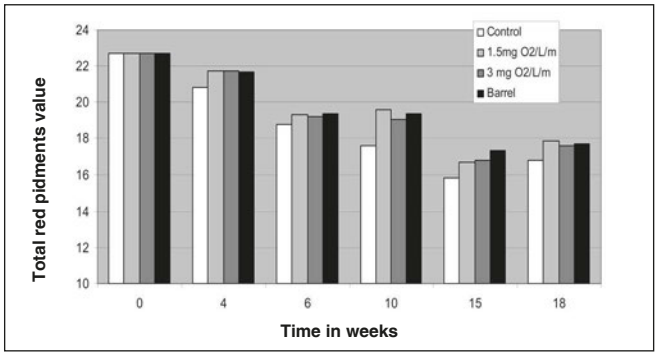

FIG 5: Total red pigment development of wine C. during micro-oxygenation treatment.

The O2 treated wines were also higher in polymeric pigment and polymeric phenols, due to acetaldehyde formation and polymerisation. The polymerisation of procyanidins in wine A was also reflected in an increase in the HCl index of the treated wines (Results not shown).

A small decrease in the total tannin concentration and a small increase in colour hue in the treated wines were observed (results not shown). The gelatin index of wine C also varied over time, but it must be kept in mind that this index only gives an indication of astringency and is not always directly correlated with it. During micro-oxygenation the wine is supposed to first go through a structuring phase with an increase in astringency. This is followed by a phase where softening of the wine occurred. If too much micro-oxygenation is applied for too long a period of time the wine can become hard or "dried" out. These phases has however not been scientifically proven, but it has been found that if micro-oxygenation is applied for too long a period of time the mean degree of polymerization of catechins increases to a large extend and the wine can become too hard. Research has also showed that the decrease in anthocyanin level was also higher where larger percentages of oak were added to the wine. This is probably due to oak tannins being oxidized easier that grape tannins, leading to enhanced polymerization.

It thus seems that micro-oxygenation is most effective in terms of colour development when applied before or after malolactic fermentation. It is doubtful whether a wine, which is older than 6 months, will still benefit from micro-oxygenation for its colour. We have also seen that the colour of wines with a high colour density (<15) after malolactic fermentation does not increase to such a large degree if micro-oxygenation is applied that it can be observed with the naked eye. Micro-oxygenation can however be a useful tool if applied to young red wines to increase the colour.

It is clear that the sensory monitoring of wine during micro-oxygenation is still very important and will be discussed in more detail in the next article.

Acknowledgements

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References

Boulton, R., 2001. The copigmentation of anthocyanins and its role in the color of red wine: a critical review. Am. J. Enol. Vitic. 52, 67-87.

Du Toit, W.J., K. Lisjak, J. Marais & M. du Toit 2006. The effect of micro-oxygenation on the phenolic composition, quality and microbial composition of South African red wines. South African Journal of Enology and Viticulture. 27, 57-67.

Du Toit, W.J., J. Marais & M. du Toit. Oxygen in wine: a review 2006. South African Journal of Enology and Viticulture. 27, 76-94.

Iland, P., Ewart, A., Sitters, J., Markides, A. & Bruer, N., 2000. Techniques for chemical analysis and quality monitoring during winemaking. (1st Edition). Patrick Iland wine promotions. Campbelltown, Australia.

Nikfardjam, M. & Dykes, S., 2003. Micro-oxygenation research at Lincoln University Part 3: Polyphenolic analysis of Cabernet Sauvignon wine under the application of micro-oxygenation. The Austr. New Zeal Grapegr. & Winemaker 468, 41-44.

Parish, M., Wollan, D. & Paul, R., 2000. Micro-oxygenation-a review. The Austr. New Zealand Grapegrower & Winemaker Annual Technical Issue 438a, 47-50.

Ribéreau-Gayon, P., Glories, Y., Maujean, A. & Dubourdieu, D., 2000. Handbook of Enology, Volume 2: The chemistry of wine stabilization and treatments. Ed. Ribéreau-Gayon P., Wiley, Chichester, England.

Micro-oxygenation in South Africa: Part 2 Effect on the sensorial and microbial aspects of wine

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This is the second article on micro-oxygenation. The first article focussed on the effect of micro-oxygenation on the phenolic and colour composition of red wine. The addition of oxygen will however also influence other characteristics of the wine. These include the sensorial properties and microbial composition and will be discussed in this article. Some guidelines regarding the use of micro-oxygenation will also be given.

Experimental observations

Materials and Methods

Micro-oxygenation is supposed to induce different positive sensorial characteristics to the wine according to the suppliers of micro-oxygenation equipment. These include an increase in colour, softening of tannins and the removal of unwanted aromas such as certain vegetative and sulphur like aromas. We decided to investigate some of these claims by conducting sensorial analyses of two different red wines, which had undergone micro-oxygenation. These wines were a 2002 Cabernet Sauvignon (wine A) and a 2004 Pinotage. Wine A was treated with 0mg O_2/L/month, 1.5mg O_2/L/month and 3mg O_2/L/month. Wine B was treated with 0mg O_2/L/month, 1.5mg O_2/L/month and 3mg O_2/L/month in contact with American oak staves which had 50% of the internal surface of an oak barrel. The same wine was also stored in a new American oak barrel from the same cooperage as a reference.

At the tastings expert wine tasters were used, consisting mostly of oenologists from the Pinotage Association and a major cooperage. Tastings was done blind in a temperature controlled tasting room in standard ISO wine tasting glasses. Triangular tastings were held to distinguish between different treatments in wines A and B and an unstructured line scale to indicate intensities of certain flavours in wine B. The relevant statistics were applied to all the data.

Acetic acid bacteria and Brettanomyces counts were performed on selective media in wine B during the treatments.

Results and Discussion

In wine A, a very full bodied high phenol wine, the tasters were able to distinguish between the control (no O_2 added) and the 3 O_2 mg/L/month eight weeks after the treatment started, but not between the control (0 mg O_2/L/month) and 1.5mg O_2/L/month treatment at this stage. After 12 weeks, however, they could distinguish all three wines from each other.

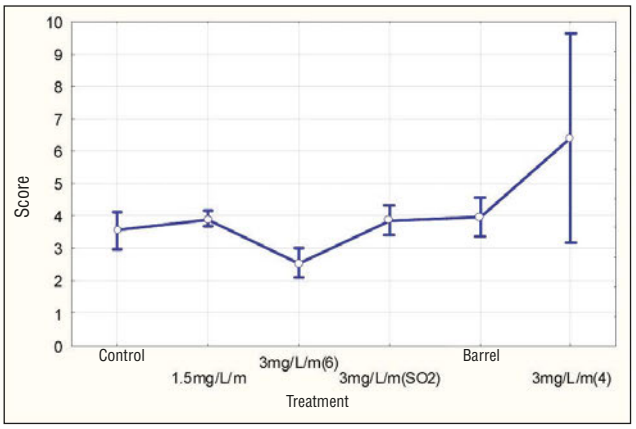
Wine B was tasted twice. In the first tasting (after three months) the panel could not statistically distinguish between the control, the 1.5 and3 mg O_2/L/month treatments, and the barrel wine on an intensity tasting for bitterness and astringency (results not shown). The wine matured in the barrel was however rated much higher for oak wood character and lower for fruitiness.

After six months of micro-oxygenation the same tendencies were observed, with the barrel matured wines having higher oak associated flavours (Figure 1). This indicate that the oak used for the barrels were not of the same treatment and/or composition as those used to produce the staves, although both were American oak from the same supplier. Winemakers should thus also note the quality of staves when using micro-oxygenation.

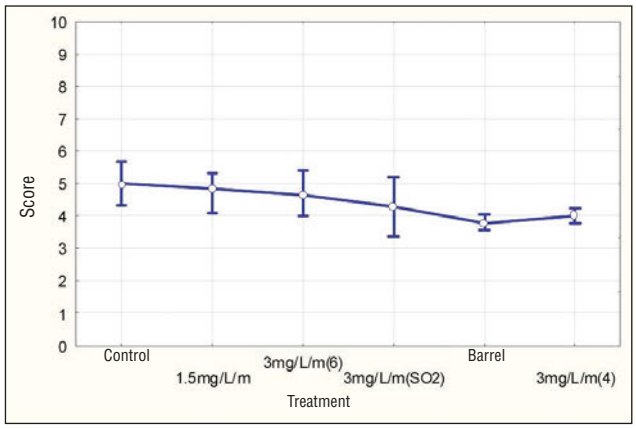
Oxidised/aged and barnyard/medicinal flavours were higher in the 3mg O_2/L/month treatment after 6 months in wine B. The panel however did not statistically prefer the barrel, 0mg O_2/L/month and 1.5mg O_2/L/month wines over each other. They did however prefer the 3mg O_2/L/month treatment the least at this stage, due to the above mentioned negative flavours being formed. This was probably due to the micro-oxygenation being applied for too long a period of time, with free SO_2 levels dropping to lower than 20mg/L. Nikfardjam & Dykes (2003) also found that when micro-oxygenation is applied for too long that the wine becomes too astringent. This correlates with a mean degree of polymerisation of procyanidins that is too high.

We are currently busy investigating the effect of using barrels and oak staves made from the wood destined for producing barrels with micro-oxygenation. Preliminary results indicate that a panel found it much more difficult to distinguish between the barrelled and micro-oxygenated treated wines using these staves if the oak stave concentration was correct.

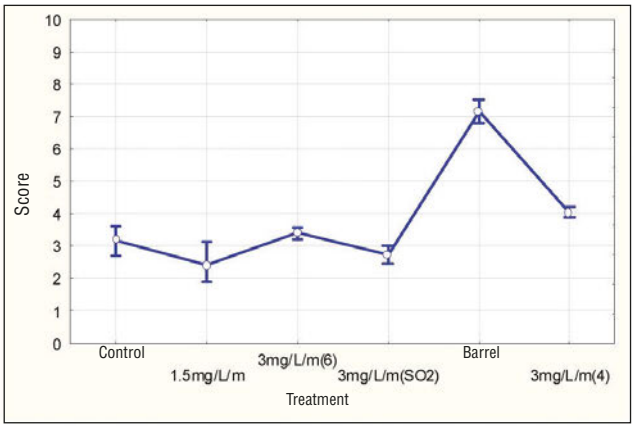
It is also true that when micro-oxygenation is applied for too long the wine can become over-aged/developed, with a decrease in quality. The barnyard/medicinal aromas normally associated with Brettanomyces spoilage, also correlated with the increase in Brettanomyces counts after 14 and 20 weeks in the 1.5mg O_2/L/month and 3mg O_2/L/month treatments (Figure 2). Acetic acid bacteria counts were also higher in the micro-oxygenation wines, although growth was not observed from the beginning of the treatment (Figure 3). No increase in volatile acidity was observed. It is thus also doubtful whether micro-oxygenation is effective in an older red wine because the panel



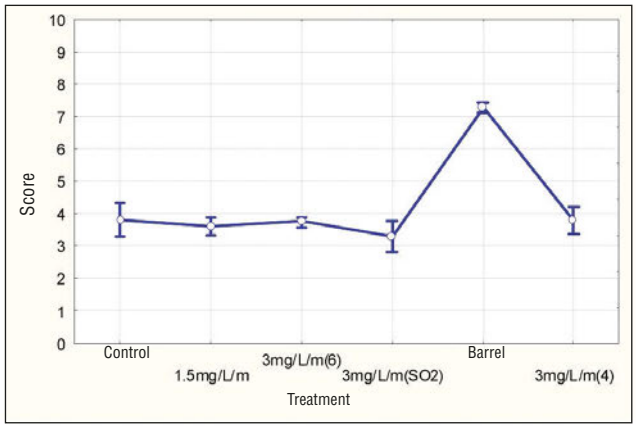
Spicyness (a)



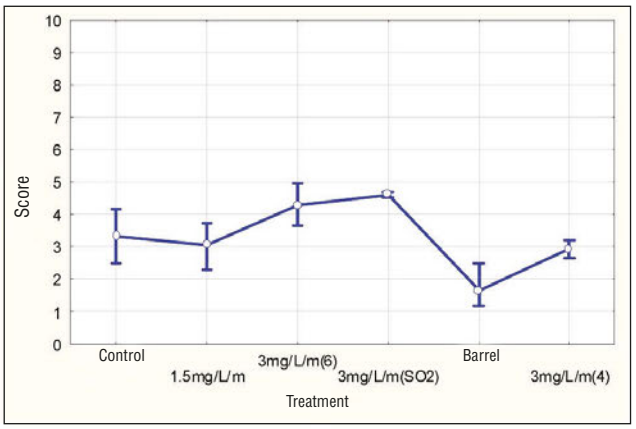
Fruitiness (b)



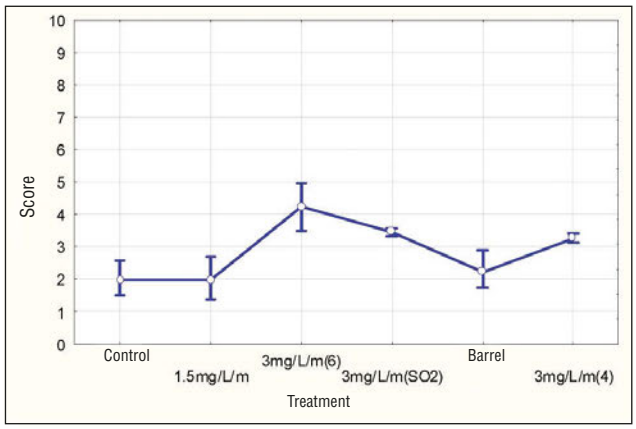
Vanilla/butterskotch (c)



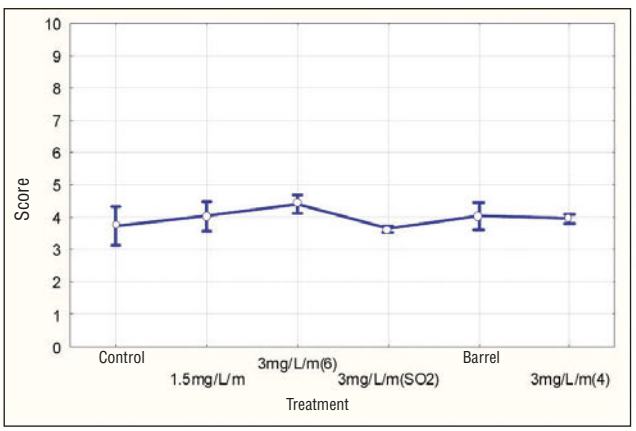
Oak/coconut (d)



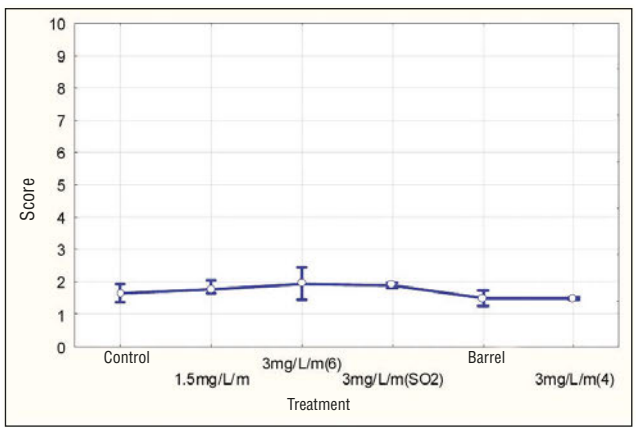
Barnyard/medicinal (e)



Oxidised/aged (f)



Astringency (g)



Bitterness (h)

FIG 1: Different sensory attributes of wine B after 6 months of micro-oxygenation (6). In the 3 mg O^2/L/month treatment wines, were also evaluated after 4 months (4), as well as to which SO_2 was added prior to the tasting (SO_2). Vertical bars denote 0.95 bootstrap confidence interval.

did not have a clear preference for the O_2 treated wines over the control. Micro-oxygenation has also been shown to lead to a decrease in unwanted sulphur compounds, even at low concentrations when applied in red wine.

Recommendations

When applying micro-oxygenation a few guidelines should be adhered to. The first step is to decide on a dosage. This is quite a difficult decision, due to red wines differing so much in terms of their phenolic composition. When the wine has a high phenolic content, such as 40-60 at 280nm 3-4mg O_2/L/month can be supplied, especially if phenolic development and colour change is required. Total tannins should also be higher than 1 g/L and that of anthocyanins preferably more than 500mg/L. For the removal of sulfur compounds lower dosages can probably be used.

We also noted that often winemakers in SA will use micro-oxygenation only for 2-3 weeks at a dosage of 0.5-1mg O_2/L/month. It is very doubtful if this low dosage for such a short period of time will lead to any changes in the wine. Red wine can actually accommodate more O_2 than one normally think, if applied in a controlled manner.

It is also better to induce the O_2 to the wine as soon as possible, either in the form of macro-oxygenation (2-4 mg O_2/L/day) just before malolactic fermentation or micro-oxygenation just after malolactic fermentation (2-4 mg O_2/L/month). Currently computer programmes exist which take into account the HCl index (level of polymerization of tannins), colour density, total phenolics, etc to decide on a micro-oxygenation dosage. This programme however determines the dosage to a large extent on the phenolic maturity of the wine, which is determined by taste. The HCl index also does not always seem to work efficiently in young SA red wines.

The best way to monitor the progression of micro-oxygenation is still by taste. Wine undergoing micro-oxygenation should be assed at least once every one to two weeks when undergoing micro-oxygenation. There is a perception that red wines first become more astringent when undergoing micro-oxygenation and then later softer, but this has not been proved conclusively. It is, however, true that if the process is applied for too long a period, the wine's tannins can become dry and harsh. The wine's nose would also be assessed for the typical oxidation aromas, as well as a loss of fruit. When this happens the micro-oxygenation should be terminated.

Sulphur dioxide levels should also be checked at least once a month and kept at around 25mg/L free. Higher levels than this will probably inhibit the positive effect of adding small amounts of O_2 to the wine, while free levels lower than 20mg/L seems to increase the risk of Brettanomyces infection. When Brettanomyces infection is suspected in a red wine micro-oxygenating should not be applied at all. Brettanomyces numbers can also be monitored with selective plating, but it can happen that volatile phenols already forms in the wine when the winemaker is waiting for the results, which might take up to two weeks. Hopefully new quicker DNA based techniques to detect Brettanomyces in wine might rectify this situation in future. Micro-oxygenation does not seem to lead to an increase in VA due to acetic acid bacterial growth (if tanks are filled completely), but this can also be assessed regularly. The wine's temperature should also be around 18-20°C, much lower temperatures than this can lead to O_2 accumulation in the wine and much higher temperatures to not sufficient O_2 dissolving in

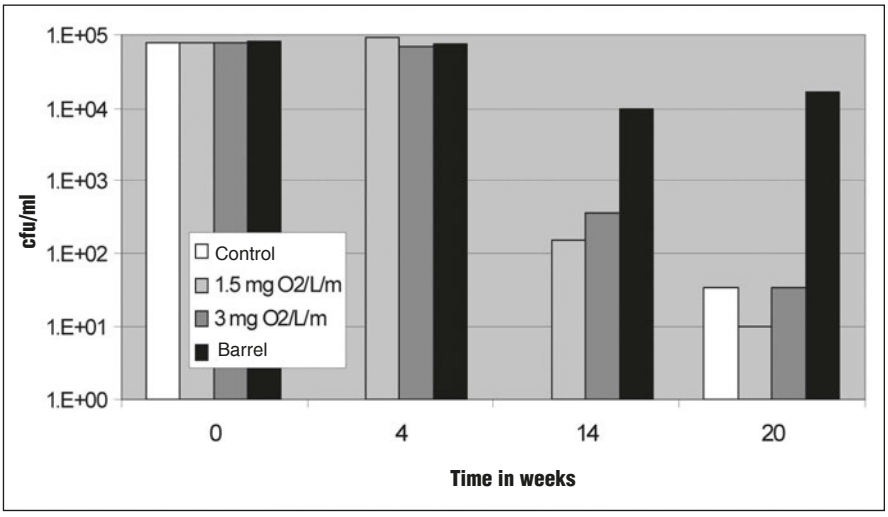


FIG 3: Acetic acid bacterial numbers in wine B during micro-oxygenation treatment.

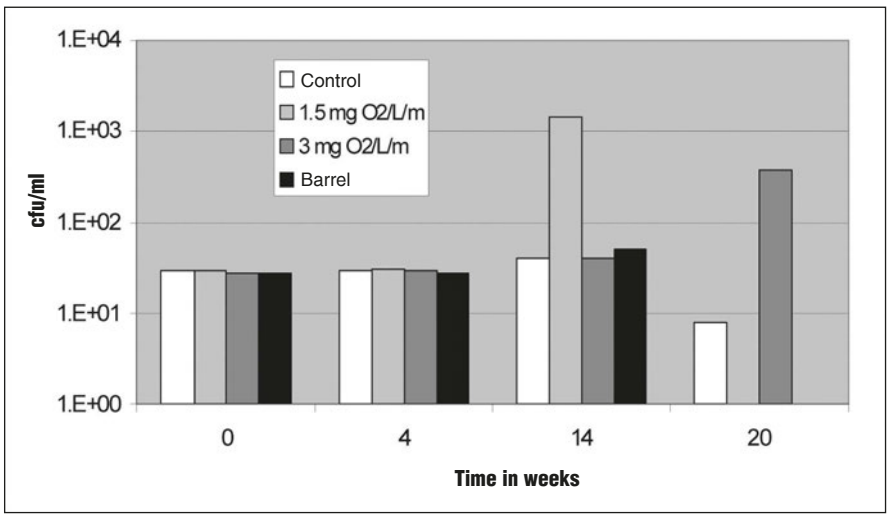


FIG 2: *Brettanomyces* in wine B during micro-oxygenation treatment.

the wine. Also refer to the first article regarding more practical recommendations.

Micro-oxygenation is a technique that can be used efficiently by winemakers to bring about certain positive changes to the wine – if used correctly. Many questions still remain regarding micro-oxygenation, such as if used with oak staves a barrel can be simulated and its effect on aroma compounds in wine. We are continuing with our research on micro-oxygenation and will publish new data regarding these aspects in future.

Acknowledgements

I would like to thank Reines Trading (agents for Parsec in South Africa) for the use of the micro-oxygenation equipment, Winetech for financial support, D.P. Groenewald and L. Kotzé for technical support and Members of the South African Pinotage Association who participated in the tastings.

Literature cited

Basker, D., 1988. Critical values of difference among rank sums for multiple comparisons by small taste panels. Food Techn. 41, 88-89.

Du Toit, W. J. & Pretorius, I. S., 2002. The occurrence, control and esoteric effect of acetic acid bacteria in winemaking. Ann. Microbiol. 52, 155-179.

Du Toit, W. J., Pretorius, I. S. & Lonvaud-Funel, A., 2005. The effect of sulphur dioxide and oxygen on the viability and culturability of a strain of Acetobacter pasteurianus and a strain of Brettanomyces bruxellensis isolated from wine. J. Appl. Microbiol. 98, 862-871.

Du Toit, W.J., K. Lisjak, J. Marais & M. du Toit 2006. The effect of micro-oxygenation on the phenolic composition, quality and microbial composition of South African red wines. South African Journal of Enology and Viticulture. 27, 57-67.

Du Toit, W.J., J. Marais & M. du Toit. Oxygen in wine: a review 2006. South African Journal of Enology and Viticulture. 27, 76-94.

Efron, B. & Tibshirani, R.J., 1993. An introduction to bootstrap. Chapman and Hall, New York, USA.

Fourie, B. P., 2005. The influence of different barrels and oak derived products on the colour evolution and quality of red wines. M.Sc. Agric thesis, Stellenbosch University.

Monagas, M., Bartolome, B. & Gomez-Cordoves, C., 2005. Updated knowledge about the presence of phenolic compounds in wine. Crit. Rev. Food Sc. Nutr. 45, 85-118.

Nikfardjam, M. & Dykes, S., 2003. Micro-oxygenation research at Lincoln University Part 3: Polyphenolic analysis of Cabernet Sauvignon wine under the application of micro-oxygenation. The Austr. New Zeal Grapegr. & Winemaker 468, 41-44.

Nieuwoudt, H.H., Prior, B.A., Pretorius, I.S., Manley, M. & Bauer, F.F., 2004. Principal component analysis applied to fourier transform infrared spectroscopy for the design of calibration sets for glycerol prediction models in wine and for the detection and classification of outlier samples. J. Agric. Food Chem. 52, 3728-3735.

Parish, M., Wollan, D. & Paul, R., 2000. Micro-oxygenation- a review. The Austr. New Zealand Grapegrower & Winemaker Annual Technical Issue 438a, 47-50.

Puech, J. L., Feuillat, F. & Mosedale, J.R., 1999. The tannins of oak heartwood: structure, properties, and their influence on wine flavor. Am. J. Enol. Vitic. 50, 469-478.

Ribéreau-Gayon, P., Glories, Y., Maujean, A. & Dubourdieu, D., 2000. Handbook of Enology, Volume 2: The chemistry of wine stabilization and treatments. Ed. Ribéreau-Gayon P., Wiley, Chichester, England.

Santos-Buelga, C., Francia-Aricha, E. M., Du Pascual-Teresa, S. & Rivas-Gonzalo, J. C., 1999. Contribution to the identification of the pigments responsible for the browning of anthocyanin-flavanol solutions. Europ. Food Research Techn. 209, 411-415.

Silva Ferreira, A.C., Barbe, J.C. & Bertrand, A., 2002. Kinetics of oxidative degradation of white wines and how they are affected by selected technological parameters. J. Agric. Food Chem. 50, 5919-5924.

Vivas, N., Viva, N., Debèda, N., Vivas de Gaujelac, N. & Nonier, M. F., 2003. Mise en évidence du passage de l'oxygène au travers des douelles constituents les barriques par l'utilisation d'un dispositif original de mesure de la porosité du bois. Premiere resultats. Sci. des Alim. 23, 655-678.

Effect of different oxygen levels on glutathione levels in South African white must and wines

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Glutathione is an important compound in wine and also human health, due to its detoxification actions. Glutathione, a sulphur containing compound naturally occurring in grape must, has been shown to form the Grape Reaction Product (GRP). This is due to glutathione reducing quinones molecules to GRP when enzymatic oxidation of grape must takes place. This reaction is thus very sensitive to the presence of O_2 and SO_2, with the latter inhibiting oxidation enzymes. So called reductive winemaking of especially Sauvignon blanc is used extensively throughout the so-called New World. During this process O_2 and oxidation is shut out by the addition of dry ice, SO_2, ascorbic acid etc to the must and wine. This process is supposed to better preserve the flavour and aroma of especially Sauvignon blanc. It is, however, not well known just how much O_2 is displaced in a commercial cellar set up, both in the crusher and the press by these actions. White juice can easily pick up a few mg/L of O_2 during processing of the grapes. Due to glutathione's sensitivity to oxidation it has been proposed to be used as a possible marker of oxidation. New commercial presses now exist, which enables the winemaker to perform whole bunch pressing at O_2 levels lower than 0.5%. Very few studies, however, investigated the effect of different concentrations of O_2 measured in the press and must on the glutathione concentration. We thus decided to investigate the effect of adding measurable concentrations of dissolved O_2 to different SA white musts and to monitor the glutathione concentration in the must and after alcoholic fermentation.

Materials and Methods

Three different white grapes, two Sauvignon blancs (juice and wine A and C) and a Colombard (juice and wine B) were used for this study. The Sauvignon blanc grapes originated from two different vineyards in Elgin and the Colombard from Robertson. The grapes harvested when deemed optimally ripe by the winemaker and transported to Stellenbosch University. The grapes were not crushed, but whole bunch pressing was applied to avoid O_2 pick up during crushing. Whole bunches were pressed in a specially designed small scale press, where the O_2 level inside the press was maintained at <1% and this yielded juice with a dissolved O_2 concentration of less than 0.3 mg/L. The juice was collected in 4.5L glass bottles (in which the air was previously displaced with N_2 gas). By adding different amounts of O_2 to these juices three O_2 treatments were yielded: a reductive treatment where no O_2 was added and the dissolved O_2 concentration in the juice was <0.3mg/L, a control where between 1-1.5mg/L O_2 was added and an oxidative treatment where 3.5-4mg/L O_2 was added. To the reductive and control treatments 60mg/L SO_2 and 50mg/L ascorbic acid was also added. These juices was then allowed to settle over night at 15°C and racked the next day under N_2 pressure into other 4.5L glass canisters (in which the air was also dispelled with N_2). All juices were inoculated with Vin13 and DAP added at 0.5mg/L two days after the initiation of fermentation. All fermentations were performed at 15°C.

Samples for glutathione analyses, performed with LCMS-MS, were drawn from the settled juices, as well as the wine after the completion of alcoholic fermentation. To these samples a 1000mg/L SO_2 and 500mg/L ascorbic acid were added to completely inhibit any further oxidation and frozen at -20°C. Samples were also kept at 4°C and certain samples thawed after two weeks and refrozen before being analysed after four weeks. This was done to investigate the stability of glutathione over time during storage.

Results and discussion

We tested first the effect of storage on glutathione concentrations in grape must before analyses with LCMSMS. In Figure 1 the glutathione concentration in grape must stored under different conditions can be seen. It is clear that storage with no SO_2 addition and at 4°C led to a decrease in glutathione concentrations. Storage at -20°C, even if the must was thawed once and re-frozen, did not lead to significantly lower glutathione concentrations. It is thus advisable to keep must or wine samples destined for glutathione analyses at -20°C if one wants to store samples for glutathione analyses.

In Figures 2 to 3 the glutathione levels in the reduced, control and oxidative treatments of the juice and wine from grapes A and C can also be seen. It is clear that even low amounts of O_2 added to the must (such as in the control) led to a decrease in glutathione, even in the presence of SO_2 (60mg/L added). In the control 1-1.5 mg/L O_2 was added, which is relatively low compared to a commercial cellar set up, where a higher concentration of glutathione can easily be added to the must. Higher additions with O_2, as in the oxidative treatments in the absence of SO_2 and ascorbic acid led to a drastic reduction in glutathione levels in the must. The same results were obtained in the juice and wine made from grapes B. It thus seems that glutathione could be a possible marker of oxidation in the must.

Alcoholic fermentation, in this case with Vin13, also led to a reduction in glutathione concentrations. This does not mean however that Vin13 will always reduce glutathione concentration in the must. Yeast strain, initial glutathione concentration and composition of the must can all influence the evolution of glutathione during alcoholic fermentation.

Why is higher glutathione content desired in white wine? As mentioned earlier, glutathione forms the so-called GRP with oxidised phenolic compounds. This leads to the must having a less brown colour. In wine, glutathione has been proven to protect certain terpenoids, such as linalool and -terpineol, responsible for the muscat, rose and citrus characters in certain wine.

In bottled Sauvignon blanc wines, glutathione also seems to protect volatile tiols, the latter imparting the typical passion fruit to certain Sauvignon blanc wines. Commercial yeast extract, reputed to contain glutathione and which protects white wine from premature ageing and becoming yellow, can also be purchased. How effective these treatments are on the ageing capacity of South Africa white wines should, however, be investigated further. This could be crucial to the South African wine industry, where premature ageing of certain white wines seems to pose a major problem.

Acknowledgements:

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References

Bassil, D.; Makris, D.; Kefalas, P. Oxidation of caffeic acid in the presence of L-cysteine: isolation of 2-S-cysteinylcaffeic acid and evaluation of its antioxidant properties. *Food Res. Int. 2005, 38*, 395-402.

Boulton, R. B.; Singleton, V. L.; Bisson, L. F.; Kunkee; R. E. *Principles and practices of winemaking*. Ed. Boulton R. B. Chapman & Hall, New York, NY. *1996*.

Cheynier, V.F.; Trousdale, E.K.; Singleton, V.L.; Michel, J.; Salgues, R.W. Characterisation of 2-S-glutathionyl caftaric acid and its hydrolysis in relation to grape wines. *J. Agric. Food Chem. 1986, 34*, 217-21.

Cheynier, V.; Van Hulst, M. W. J. Oxidation of trans-caftaric acid and 2-S-gluthathionyl caftaric acid in model solutions. *J. Agric. Food Chem. 1988, 36*, 10-15.

Cilliers, J. L.; Singleton, V. L. Caffeic acid autoxidation and the effects of thiols. *J. Agric. Food Chem. 1990, 38*, 1789-1796.

Du Toit, W.J., Lisjak K, Stander M. and Prevoo D. 2007. Using LCMSMS to assess glutathione levels in South African white grape juices and wines made with different levels of oxygen. In press for *The Journal of Agricultural and Food Chemistry*.

Field, J. A.; Thurman, E. M. Glutathione Conjugation and Contaminant Transformation. *Environ. Sci. Technol. 1996, 30*; 1413-1418.

Lavigne, V. Pons, A and Duboudieu, D. 2007. Assay of glutathione in must and wine using capillary electrophoresis and laser-induced fluorescence detection: Changes in concentration in dry white wines during alcoholic fermentation and ageing. Journal of Chromatography, 1139, 130-135.

Marais, J. Effect of grape temperature, oxidation and skin contact on Sauvignon Blanc juice and wine composition and wine quality. *S. Afr. J. Enol. Vitic. 1998, 19*, 10-16.

Papadopoulou, D; Roussis; I.G. Inhibition of the decline of linalool and alpha-terpineol in Muscat wines by glutathione and N-acetyl-cysteine. *It. J. Food Sc. 2001, 13*, 413-419.

Park, S.K.; Boulton, R.; Noble, Formation of hydrogen sulfide and glutathione during fermentation of white grape musts. *Am J. Enol. Viticult. 2000, 51*, 91-97.

Tominaga; T.; Dubourdieu, D. Sulfur aroma precursor present in S-glutathione conjugate form: identification of S-3-(hexan-1-ol)-glutathione in must from Vitis vinifera L. cv. Sauvignon Blanc. *J. Agric. Food Chem. 2000, 50*, 4076-4079.

http//www.fst.vt.edu/extension/enology/sources.html

http// www.glutathione.antioxidant-facts.com).

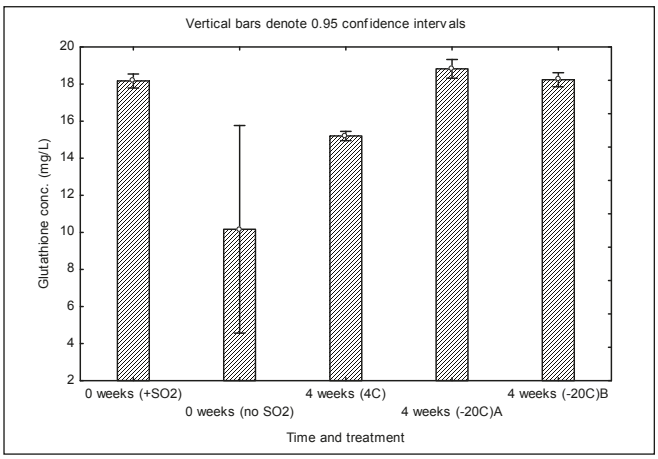

FIG 1: Reduced glutathione levels in grape juice stored under different conditions. 0 weeks (+SO_2): samples analyzed immediately after pressing, with 1000 mg/L SO_2 and 500 mg/L ascorbic acid added;

0 weeks (no SO_2): samples analyzed immediately after pressing, with no SO_2 or ascorbic acid added;

4 weeks (4C): Stored at 4 ºC for 4 weeks;

4 weeks (-20C) A: Stored at -20 ºC for 4 weeks. Sample thawed only once,

4 weeks (-20C) B: Stored at -20 ºC for 4 weeks. Sampled thawed twice. All the samples analyzed at week 4 had 1000 mg/L SO_2 and 500 mg/L ascorbic acid added initially. Different letters indicate significant differences ($p \leq 0.05$). (Du Toit *et al*, 2007).

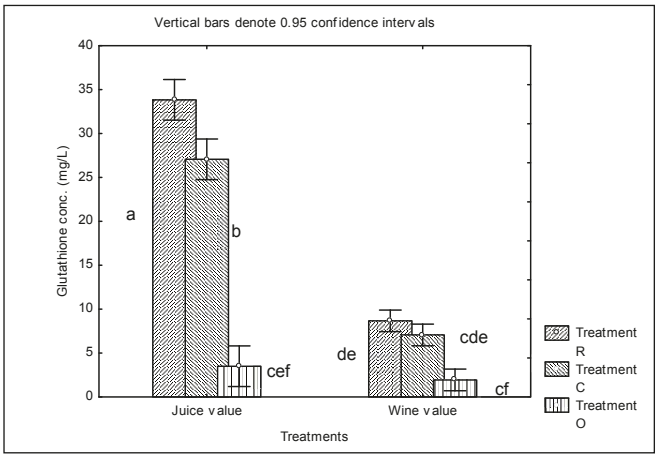

FIG 2: Reduced glutathione concentrations in juice and wine A, which underwent different treatments. Treatment R: Reductive treatment of juice, Treatment C: Control treatment of juice, Treatment O: Oxidized treatment of juice. Different letters indicate significant differences ($p \leq 0.05$). (Du Toit *et al*, 2007).

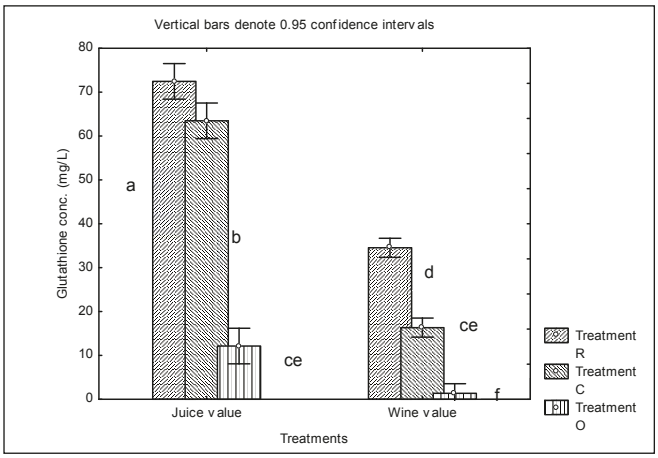

FIG 3: Reduced glutathione concentrations in juice and wine C, which underwent different treatments. Treatment R: Reductive treatment of juice, Treatment C: Control treatment of juice, Treatment O: Oxidized treatment of juice. Different letters indicate significant differences ($p \leq 0.05$). (Du Toit *et al*, 2007).

Enhancement of Sauvignon blanc wine aroma through yeast combinations

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Introduction

The flavour or aroma of wine is one of the most important factors when determining quality and intrinsic value. Even small variations in the occurrence and concentration of volatile flavour components may account for the difference between a premium, gold medal winner and an ordinary table wine. It is common knowledge that consumers tend to purchase wine "with the nose".

Some of the most distinct flavour components encountered in wine are the volatile thiols, especially 4-mercapto-4-methylpentan-2-one (4MMP), 3-mercaptohexan–1-ol (3MH) and 3-mercaptohexyl acetate (3MHA). The term *thiol* or *mercapto* refers to the sulphur-containing functional SH-group (sulphur and hydrogen) present in these components. The perception threshold values are 0.8ng/L for 4MMP, 60ng/L for 3MH and 4ng/L for 3MHA, which explains why these components are so distinctly perceptible. To illustrate this point, theoretically 1 mg of pure 4MMP is able to adjust the aroma of one million litres of wine!

In Sauvignon blanc wine, these components are extremely important with regard to the cultivar character, since they contribute to the characteristic cultivar flavour which is reminiscent of boxwood (4MMP), passion-fruit, grapefruit, gooseberry and guava (3MH and 3MHA) (Dubourdieu et al., 2006). The flavour components, 4MMP, 3MH and 3MHA have been identified in various concentrations in wines made from Riesling, Colombard, Sémillon, Cabernet Sauvignon and Merlot grapes, and might well influence the flavour of these cultivars (Tominaga et al., 2000; Murat et al., 2001b).

Sauvignon blanc wines have characteristic flavour profiles which may be described as capsicum, asparagus, boxwood, tomato leaf, grapefruit, gooseberry and passion-fruit. Work by Augustyn (1982) and later Allen (1991) identified the methoxypyrazines, specifically isobutyl-methoxypyrazine (IBMP), as the predominant flavour component that determines capsicum and asparagus flavours. Methoxypyrazines derive exclusively from the grape and are largely influenced by the microclimate of the vineyard, where shaded grape bunches usually have higher IBMP concentrations compared to bunches that are exposed to the sun (Marais et al., 1999).

On the other hand, the volatile thiols are practically absent in grape juice and develop only during the fermentation process. This explains the commonly held notion that the wine yeast *Saccharomyces cerevisiae* is responsible for the formation of volatile thiols during fermentation. However, yeasts do no synthetise this kind of volatile thiol *de novo*. Darriet et al. (1995) found that 4MMP and 3MH occur in the grape in the form of aroma-free, non-volatile, cysteine-bound compounds and that yeast is only involved in splitting the aromatic thiols from the aroma-free grape precursor compounds.

An enzymatic mechanism for the release of thiols was suggested after it was found that a bacterial enzyme extract containing carbon sulphur lyase enzymes, was able to release 4MMP from the precursor S-4-(4-methylpentan-2-one)-L-cysteine (Cys-4MMP) (Tominaga et al., 1995). It was then suggested that the enhancement of Sauvignon blanc specific cultivar flavours during fermentation possibly occurred through the action of yeast carbon sulphur lyases. Researchers at the Australian Wine Research Institute (AWRI) in Adelaide investigated how the ability of yeasts to release 4MMP from Cys-4MMP, was influenced when their carbon sulphur lyase coding gene was removed. Four laboratory yeast genes suspected of coding for carbon sulphur lyase enzymes, were found to influence the release of the volatile thiol 4MMP. These research results indicated that multiple genes were possibly involved in the release mechanism. These findings were also confirmed in a commercial wine yeast, thereby indicating that the removal of the four suspected carbon sulphur lyase genes resulted in a reduction in the amount of 4MMP released (Howell et al., 2005). AWRI researchers showed furthermore that the volatile thiol 3MHA was formed by yeast from 3MH through the action of the ester forming enzyme, alcohol acetyl transferase (Swiegers et al., 2006b). This work first proved the relationship between the volatile thiol and ester metabolisms of yeast cells. This enzymatic release mechanism was recently confirmed when the same researchers showed that excessive expression of a bacterial carbon sulphur lyase gene in a wine yeast resulted in a dramatic increase in the concentration of volatile thiols (Swiegers et al., 2007). In this study Sauvignon blanc grapes from a warm Australian wine region (Riverland) were used to make *experimental* wine using the latter yeast, thereby causing the passion-fruit flavour in the wine to increase dramatically (Figure 1). It is important, however, to note that current Australian policy does not provide for any *commercial* wine to be made using genetically modified (GMO) yeast strains (Swiegers et al., 2007). The wine yeast mentioned above that contains the bacterial carbon sulphur lyase gene is used purely as an experimental model to investigate the underlying mechanisms for thiol release.

Professor Denis Dubourdieu's research group in Bordeaux proved that when the concentration of a pre-added, chemically synthetised Cys-3MH-precursor compound in model fermentations decreased during the fermentation process, the 3MH-concentration increased. However, only a small part (1.6% on the sixth day of fermentation) of the precursor

compound was released as 3MH. This means that wine yeasts have a limited ability to release volatile thiols (Dubourdieu et al., 2006). In Cabernet Sauvignon and Merlot grape must it was proved that the amount of 3MH released, corresponds proportionally to the Cys-3MH-concentration in the unfermented grape juice. The higher the concentration of the thiol precursors in the grape juice, the higher the volatile thiol concentration in the wine (Murat et al., 2001b). The fact that only 3.2% of the Cys-3MH-precursor in the latter study was released during fermentation, confirmed that most wine yeasts had a very limited ability to release volatile thiols in wine. In other words, wine yeasts do not have the ability to develop the full aroma potential of grape must and therefore a large source of flavour in the grapes remains unused.

Research has shown that the amount of 4MMP released during fermentation depends on the type of yeast strain used to complete the fermentation (Dubourdieu et al., 2006). It seems therefore that the genetic and physiological characteristics of the particular yeast strain have a significant effect on its ability to release thiols. Research at the AWRI confirmed these findings by showing that different wine yeast strains have varying abilities to release 4MMP from the Cys-4MMP-precursor in model fermentations (Howell et al., 2004). The ability of different commercial wine yeast strains to convert 3MH to 3MHA was also further investigated. Large variations in the ability of commercial wine yeasts to convert 3MH were observed and in most instances this did not correlate with the ability to release 4MMP (Swiegers et al., 2005). In a more recent study AWRI researchers showed that different commercial wine yeast strains, as a result of the variation in thiol release, may adjust the aroma of Sauvignon blanc dramatically. In this study Anchor VIN7 resulted in the highest 4MMP concentration and Anchor VIN13 in the highest 3MH concentration (Swiegers et al., 2006a). Winemakers preferred the wines made with yeasts that release high concentrations of thiols. A correlation therefore seems to exist between wine preference and thiol concentrations in certain wine styles.

Co-inoculations refer to the simultaneous inoculation of two or more yeasts in a given grape juice. The yeasts conduct the fermentation jointly. Previous research has shown that co-inoculations of several yeast strains adjust the chemical and sensorial characteristics of wine, compared to single yeast strain fermentations or an equal blend of single yeast strain fermentations (Rojas et al., 2003; Howell et al., 2006). Our hypothesis is that yeast strains interact and exchange metabolites during a co-fermentation. This hypothesis was partly proved by comparing the redox potential of co-fermentations to single yeast strain fermentations (Cheraiti et al., 2005). The purpose of the study below was to determine whether co-inoculations of two or more commercial wine yeast strains enhance the aroma profile, especially the volatile thiols, of Sauvignon blanc wine. The studies were conducted on 2006/2007 Sauvignon blanc grapes from the Adelaide Hills (Adelaide, Australia).

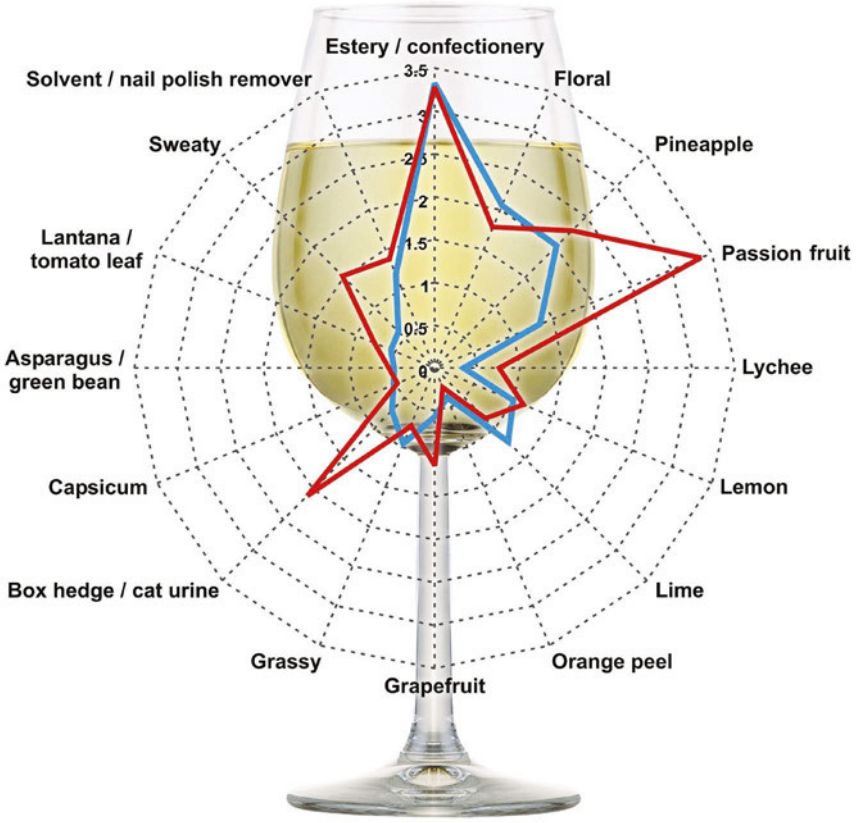

FIG 1: The aroma profile of Sauvignon blanc wine (Riverland, Australia) fermented with VIN13 (blue line) and VIN13(CSL1) (red line) yeasts. The VIN13(*CSL1*) yeast has increased carbon sulphur lyase activity which causes dramatically more volatile thiols to be released during wine fermentation (Swiegers et al., 2007). [This figure was reprinted with permission from the *Australian Wine Industry Technical Conference*].

TABLE 1: Basic chemical analysis of wines after bottling. Values represent the average of triplicate fermentations.

Yeast strain(s)	pH	Titratable acid (g/L)	Volatile acid (g/L)	Alcohol (% v/v)
VIN 7	3.3	7.6	0.84	12.9
QA23	3.3	6.8	0.40	12.9
VIN 7 / QA23*	3.3	7.0	0.45	12.9
VIN 7 + QA23†	3.2	7.2	0.53	12.9

* Co-inoculation
† 50% wine blend

TABLE 2: Basic chemical analysis of wines after bottling. Values are the average of triplicate fermentations.

Yeast strain (se)	pH	Titratable acid (g/L)	Volatile acid (g/L)	Alcohol (% v/v)
Alchemy I	3.5	5.5	0.17	11.9
Alchemy II	3.5	5.4	0.21	11.9
Yeast combination III	3.5	5.6	0.29	11.9
A	3.5	5.6	0.31	11.9
B	3.5	5.6	0.15	11.9
C	3.5	5.6	0.16	11.9
D	3.5	5.6	0.28	11.9

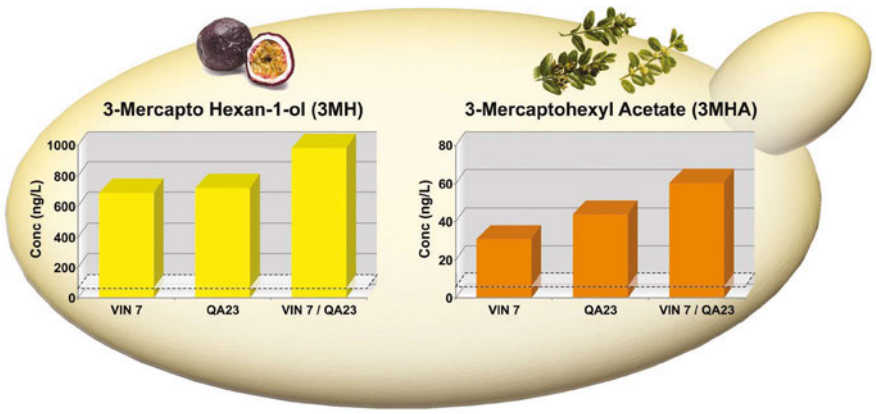

FIG 2: Volatile thiol concentrations (ng/L) (*Conc.*) in Sauvignon blanc wines fermented using VIN7, QA23 and VIN7/QA23 co-inoculation. The VIN7/QA23 co-inoculation resulted in the highest concentration of 3-mercaptohexan-1-ol (3MH) and 3-mercaptohexyl acetate (3MHA). This figure was reprinted with permission from the *Australian and New Zealand Grapegrower and Winemaker*.

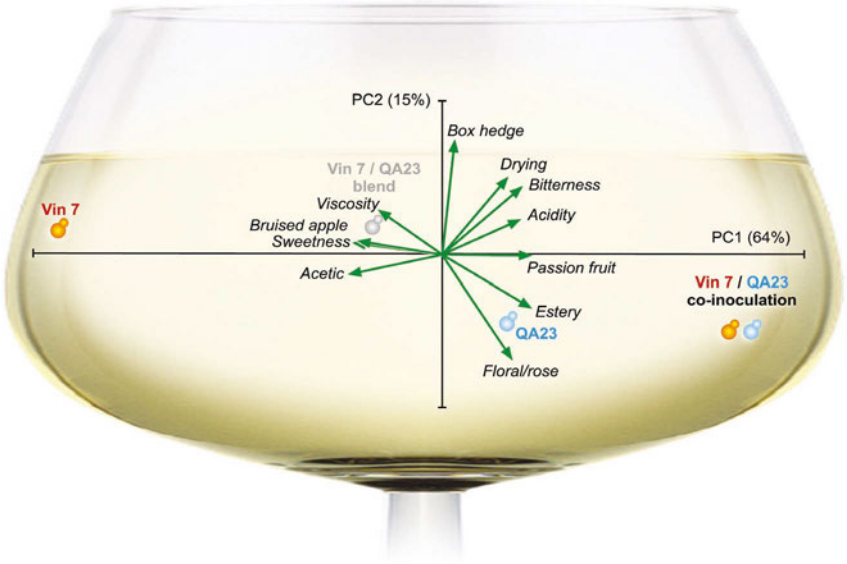

FIG 3: Principal Component Analysis (PCA) biplot of the descriptive sensorial analysis of the VIN7, QA23, VIN7/QA23 co-inoculation and VIN7 + QA23 blended wines (n= 12 judges, 3 fermentation repetitions and 2 representation repetitions). The yeast cells (circles) represent the corresponding wines and if they are in the same vicinity as the sensorial descriptions, a correlation is indicated. VIN7 wines were in the same vicinity as acetic acid and QA23 wines in the vicinity of estery; floral/rose flavours. The VIN7/QA23 wine blend, which derives from a 50:50 blend of single yeast strain fermentation wines, was between VIN7 and QA23. The VIN7/QA23 co-inoculation wines were highest in estery; floral/rose and passion-fruit flavours.

Experimental procedure

In 2006 unfiltered and homogenised Sauvignon blanc juice was fermented using two commercial yeast strains, Anchor VIN7 and Lalvin QA23, as well as a 50:50 combination of Anchor VIN7 / Lalvin QA23. In 2007 the Sauvignon blanc juice was fermented using three experimental yeast combinations, Anchor Alchemy I, Anchor Alchemy II and yeast combination III, as well as four standard commercial yeast strains (some of which occur in the Alchemy yeast combinations). The yeast cells were inoculated in active, dry form at 30 g/HL to produce a cell population of 5 X 10^6 cells/ml in the grape must. Fermentations were executed at 15°C in 20-L closed, stainless steel cylinders. Sugar concentrations were monitored during the fermentation process. The identity of the yeast strains in the lees was determined once the fermentations were completed. Chemical analyses of the wines, including pH, titratable acid, residual sugar, alcohol and volatile acid, were conducted after bottling by the analytical services of the AWRI. Two months after bottling a formal, descriptive sensorial analysis of the 2006 wines was conducted by 12 trained judges. Thiol analyses were conducted by the SARCO Laboratoire in France.

Results

Fermentation and chemical analysis of the 2006 Adelaide Hills Sauvignon blanc wines

All the wines which were made with VIN7, QA23 and the VIN7/QA23 co-inoculation fermented dry. Residual sugar concentrations were below 3 g/L. The VIN7/QA23 co-inoculation had similar fermentation tempos to that of the QA23 fermentations, while the VIN7 fermentations were slightly slower. In the VIN7/QA23 co-inoculation

both yeast strains were present at the end of the fermentation. However, the initial 50:50 VIN7/QA23 inoculation ratio was adjusted during the fermentation process to the extent that VIN7 made up only about 10% and QA23 90% of the yeast population at the end of the fermentation. The reason for this phenomenon could possibly be because VIN7 usually has a slow fermentation tempo. Nevertheless it did not have a dramatic influence on the overall fermentation.

Table 1 indicates the basic chemical analysis of the wine. All parameters between the different fermentations were relatively the same, except for the volatile acid which varied considerably. The VIN7 wines had the highest volatile acid concentrations (0.84g/L). The VIN7/QA23 co-inoculation wine had a lower volatile acid concentration (0.45g/L), closer to the volatile acid concentration of the QA23 wine (0.40g/L). It was interesting to see that the VIN7/QA23 co-inoculation wine had lower volatile acid concentrations than the VIN7+QA23 wine blend (consisting of 50% VIN7 wine and 50% QA23 wine). This data, together with the aroma data below, proves that co-inoculations result in a unique wine aroma profile, which cannot be emulated by wine blends.

Chemical analyses of the wines' aroma components showed that the co-inoculations resulted in a more complex composition of esters, higher alcohols and volatile acids (data not shown). In the case of volatile thiols, the analyses showed that the VIN7/QA23 co-inoculation wines had the highest concentration of 3MH and 3MHA (Figure 2). The 3MH and 3MHA flavour components produce grapefruit/passion-fruit and passion-fruit aromas respectively. The data indicates that the co-inoculations resulted in wines with enhanced aroma profiles.

The formal descriptive sensorial analysis showed that VIN7 wines had the highest acetic acid character which was caused by the high volatile acid concentration (Figure 3). The QA23 wines were high in floral/rose aromas and estery characters. As expected, the VIN7+QA23 wine blend had intermediary characters. The VIN7/QA23 yeast blend wines had the highest estery, floral/rose flavours and passion-fruit characters,which correlates with the high 3MH and 3MHA concentrations.

Fermentation and chemical analysis of the 2007 Adelaide Hills Sauvignon blanc wines

The three yeast combinations and the four commercial yeast strains fermented dry. Yeast strain C fermented the quickest, followed by Alchemy I, Alchemy II and yeast combination III, yeast strain B, yeast strain D and yeast strain A. Table 2 indicates the basic chemical analyses of the wines. All parameters, except for the volatile acid, were relatively constant among the wines.

Volatile thiol analyses indicated that Alchemy I and Alchemy II resulted in the highest 3MH and 3MHA concentrations in the wines (Figure 4). Informal trials in the Australian wine industry indicated that these yeast combinations resulted in highly aromatic white wines (especially Sauvignon blanc) with citrus and passion-fruit flavours, most likely as a result of the high thiol concentrations. These wines are currently subject to a formal sensorial analysis.

Conclusion

Co-inoculations, using both VIN7/QA23 and the Anchor Alchemy yeast combinations, have enhanced chemical and sensorial aroma profiles when compared to single yeast strain fermented wines and blends of the latter single yeast strain fermentation wines. This phenomenon is most likely due to metabolic interactions between wine yeasts (Howell et al., 2006). At the moment very little information is available about the metabolic interaction of various wine yeasts during fermentation. Researchers at the AWRI are currently involved in generating more information about possible yeast-yeast interactions during wine fermentation.

The low thiol concentrations of yeast combination III compared to Alchemy I and Alchemy II emphasise the importance of correct ratios of yeasts in a yeast combination, seeing that all three combinations contain the same yeasts in different ratios. It was interesting to note than no 4MMP could be measured in the 2007 wines. This may be due to the dramatic climatic conditions in Australia during the 2006/2007 period, when the country suffered a severe drought. Due to the composition of yeast combination III, it is expected to have high 4MMP concentrations provided sufficient precursors are available in the grapes.

Sauvignon blanc wines produced using VIN7/QA23 co-inoculations had increased passion-fruit and floral flavours. Preliminary data indicate that the Alchemy I and Alchemy II yeast combinations resulted in increased

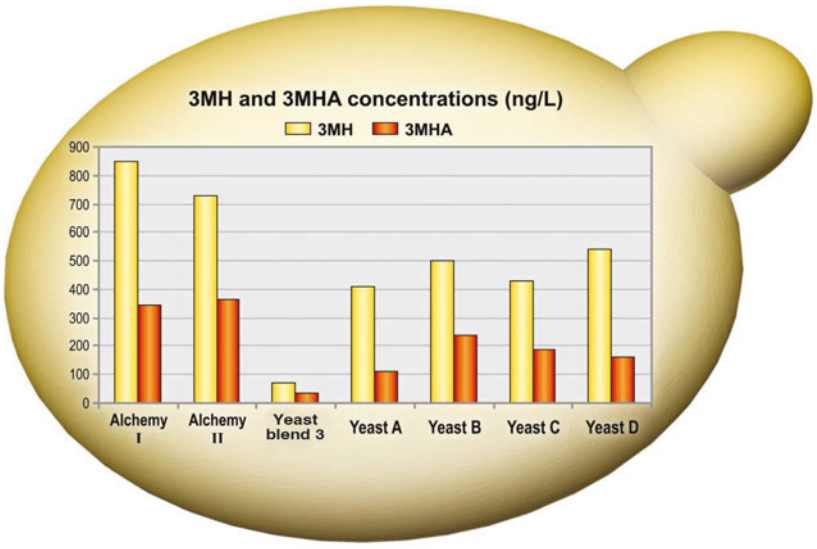

FIG 4: Volatile thiol concentrations (ng/L) in Sauvignon blanc wines fermented with the three yeast combinations and commercial yeast strains A, B, C and D. The Alchemy I and II yeast combinations resulted in the highest concentration of 3-mercaptohexan-1-ol (3MH) and 3-mercaptohexyl acetate (3MHA). The Anchor Alchemy I and II consist of different combinations of some of the commercial yeast strains A-D. The data indicates that higher volatile thiol concentrations may be obtained using the correct yeast combinations instead of single yeast strains.

fruity flavour in white wines, especially Sauvignon blanc. Future research at the AWRI aims to determine the relationship between fruity white wines and consumer preferences. In today's competitive wine market it is imperative for the consumer to be one of the most important focus points in our thinking around technological development for the wine industry.

From the above study it is clear that yeast combinations are potentially a powerful mechanism to increase fruitiness in white wines, thereby increasing the wine's consumer appeal. The Anchor Alchemy yeast combination series, which was developed in collaboration with the AWRI, will be available commercially in certain countries in 2008.

Acknowledgement

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Bibliography

Allen, M.S., Lacey, M.J., Harris, R.L.N., Brown, W.V. 1991. Contribution of methoxypyrazines to Sauvignon Blanc aroma. Am. J. Enol. Vitic., 42, 109 - 112.

Augustyn, O.P.H., Rapp, A., Van Wyk, C.J. 1982. Some volatile aroma compounds of Vitis vinifera L. cv. Sauvignon Blanc. S. Afr. Enol. Vitic., 3, 53 - 60.

Cheraiti, N., Guezenec, S., Salmon, J.M. 2005. Redox interactions between *Saccharomyces cerevisiae* and *Saccharomyces uvarum* in mixed culture under enological conditions. Appl. Environ. Microbiol., 71, 255 - 260.

Darriet, P., Tominga, T., Lavigne, V., Boidron, J., Dubourdieu, D. 1995. Identification of a powerful aromatic compound of Vitis vinifera L. var. Sauvignon wines: 4-Mercapto-4-methylpentan-2-one. Flavour Fragrance J., 10, 385 - 392.

Dubourdieu, D., Tominaga, T., Masneuf, I., Peyrot Des Gachons, C., Murat, M.L. 2006. The role of yeast in grape flavour development during fermentation: the example of Sauvignon Blanc. Am. J. Enol. Vitic., 57, 81 - 88.

Howell, K.S., Swiegers, J.H., Elsey, G.M., Siebert, T.E., Bartowksy, E.J., Fleet, G.H., Pretorius, I.S., de Barros Lopes, M.A. .2004. Variation in 4-mercapto-4-methylpentan-2-one release by *Saccharomyces cerevisiae* commercial wine strains. FEMS Micro. Lett., 240, 125 - 129.

Howell, K.S., Klein, M., Swiegers, J.H., Hayasaka, Y., Elsey, G.M., Fleet, G.H., Høj, P.B., Pretorius, I.S., de Barros Lopes, M.A. 2005. Genetic determinants of volatile thiol release by Saccharomyces cerevisiae during wine fermentation. Appl. Environ. Microbiol., 71, 5420 - 5426.

Howell, K.S., Cozzolino, D., Bartowsky, E., Fleet, G.H., Henschke, P.A. 2006. Metabolic profiling as a tool for revealing *Saccharomyces* interactions during wine fermentation. FEMS Yeast Res., 6, 91 - 101.

Marais, J., Hunter, J.J. and Haasbroek, P.D. 1999. Effect of canopy microclimate, season and region on Sauvignon Blanc grape composition and wine quality. S. Afr. J. Enol. Vitic., 20: 19 - 30.

Murat, M.L., Masneuf, I., Darriet, P., Lavigne, V., Tominga, T., Dubourdieu, D. 2001a. Effect of *Saccharomyces cerevisiae* yeast strains on the liberation of volatile thiols in Sauvignon blanc wine. Am. J. Enol. Vitic., 52, 136 - 139.

Murat, M.L., Tominaga, T., Dubourdieu, D. 2001b. Assessing the aromatic potential of Cabernet Sauvignon and Merlot musts used to produce rose wine by assaying the cysteinylated precursor of 3-mercaptohexan-1-ol. J. Agric. Food Chem., 49, 5412 - 5417.

Rojas, V., Gill, J.V., Piñaga, F., Manzanares, P. 2003. Acetate ester formation in wine by mixed cultures in laboratory fermentations. Int. J. Food Microbiol., 86, 181 - 188.

Swiegers, J.H., Bartowksy, E.J., Henschke, P.A., Pretorius, I.S. 2005. Yeast and bacterial modulation of wine aroma and flavour. Austral. J. Grape Wine Res., 11, 127 - 138.

Swiegers, J.H., Capone, D.L., Elsey, G.M., Sefton, M.A., Bramley, B.R., Francis, I.L., Pretorius, I.S. 2007. Engineering volatile thiol release in *Saccharomyces cerevisiae* for improved wine aroma. Yeast, 24, 561 - 574.

Swiegers, J.H., Francis, I.L., Herderich, M.J., Pretorius, I.S. 2006a. Meeting consumer expectations through management in vineyard and winery: The choice of yeast for fermentation offers great potential to adjust the aroma of Sauvignon Blanc wine. Austral. NZ. Wine Ind. J. 21, 34 - 42.

Swiegers, J.H., Willmott, R., Hill-Ling, A., Capone, D.L., Pardon, K.H., Elsey, G.M., Howell, K.S., de Barros Lopes, M.A., Sefton, M.A., Lilly, M., Pretorius, I.S. 2006b. Modulation of volatile thiol and ester aromas in wine by modified wine yeast. In Developments in Food Science 43, Flavour Science Recent Advances and Trends, Bredie WLP, Petersen MA (eds). Elsevier: Amsterdam, The Netherlands.

Tominaga, T., Masneuf, I. and Dubourdieu, D. 1995. A S-cysteine conjugate, precursor of aroma of white Sauvignon. J. Int. Sci. Vigne Vin. 29, 227 - 232.

Tominaga, T., Baltenweck-Guyot, R., Peyrot des Gachons, C., Dubourdieu, D. 2000. Contribution of volatile thiols to the aromas of white wines made from several *Vitis vinifera* grape varieties. Am. J. Enol. Vitic., 51, 178 - 181.

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The effect of smoke taint on wine after veld fires

Charl Theron

Many studies have been reported on the composition of wood smoke but the individual components responsible for the specific flavour of smoked products are still unknown. Although it was initially claimed that mainly phenols are of primary importance in the characterisation of smoke flavour another report indicated that the three phenols rated as smoky by a tasting panel do not reproduce the character precisely. The unique smoky flavour is apparently not limited to one class of compounds, but it seems that phenols and carbonyl compounds are the most important (Fiddler et al, 1970).

The acceptability of smoked foods is increasing not only as a preservative but as flavourant. The odour, composition and anti-microbial activity of wood smoke is highly dependent on the wood type. Some studies identified beech and oak as producing smoke with the best sensory properties but in Spain the use of vine shoots for the grilling of lamb and sardines is highly appreciated. Aqueous smoke preparations of vine shoots were compared with other woods. In the smoke of both woods the carbonyl derivatives were in higher concentrations than the phenol derivatives. Carbonyl derivatives like esters, aldehydes, ketones, diketones, furan and pyran derivatives are formed as result of the thermal degradation of cellulose and hemicellulose. These compounds are usually associated with caramel or burnt sugar aromas. Phenol derivatives are formed from the thermal degradation of lignin. The composition of the wood will thus determine the composition of the smoke provided that the influences generating the smoke are constant. It seems that ratios between concentrations of the main components can be used as parameters for the smoke characteristics (Guillen and Ibargoita, 1996).

It is, however, interesting to note that some of the compounds identified in the smoke of Vitis vinifera are similar to those which are related to specific flavours known in wine like the following:

- Common esters which are associated with a fruity character.
- Ethylphenol which is associated with Brettanomyces spoilage.
- Ethylguaiacol which is associated with Brettanomyces spoilage.
- Vanillin which is associated with wood maturation.

The smoke taint in wines can apparently be attributed to a wide variety of flavour compounds and the combination of the latter is mainly determined by the composition or origin of the wood. With the diversity of natural vegetation in the South African wine regions it will be a very complicated subject to research.

Veld fires occur all over the world and wine countries have to face this phenomenon which will not only have a direct physical impact on the vines but the secondary influences on the wine made from grapes exposed to the smoke resulting from the fires are unpredictable. Contrary to the negative perception concerning the smoke taint of wines the smoking of different foods is a very sophisticated profession and the most information concerning smoking as a scientific topic is in this regard.

References:

Fiddler, W., Wasserman, A.E., Doerr, R.C. 1970. A Smoke Flavor Fraction of a Liquid Smoke Solution. J. Agr. Food Chem. 8(5): 934 - 936.

Guillen, M.D., Ibargoitia, M.L. 1996. Volatile Components of Aqueous Liquid Smokes from Vitis vinifera L Shoots and Fagus sylvatica L Wood. J. Sci Food Agric 72: 104 - 110.

Screwcaps as bottle closure

The first international screwcap symposium was held in New Zealand towards the end of 2004. At this symposium it was mentioned that certain countries, especially France, Italy and the USA, were reluctant to use screwcaps for their wines. New Zealand and Australia on the other hand were among the first countries which saw merit in the use thereof. Since screwcaps ensure the retention of more carbon dioxide in young wines, cellars should take care not to bottle wines with excessively high levels of carbon dioxide in this way (Hawkes, 2005).

One of the most important reasons for concern about bottle closures is the variations that occur among the same type of closure. Although this is a common phenomenon among cork closures, it occurs with other closures as well. This is especially true with regard to the oxygen permeability of bottle closures. Excessive exposure to oxygen via the bottle closure may result in accelerated maturation, whereas limited exposure to oxygen may result in a reductive character in the wines (Phillips, 2005).

The bottling of wines with screwcaps prevents cork spoilage, ensures constant and prolonged maturation, requires lower sulphur dioxide qualities at the time of bottling and it is also easier to open such bottles. Screwcaps have been used for many years. Aluminium closures, better known as ROTE (Roll-on-tamper-evident) and ROPP (Roll-on-pilfer-proof), were introduced as early as 1960. Way back in 1933 researchers developed the most important liners for screwcaps. Well-known cellars such as Gallo have been using screwcaps for more than 30 years. However, the success of screwcaps is determined mainly by the suppliers, the integrity of the glass bottles and the application of the closure to the bottle.

There are various suppliers of screwcaps throughout the world and by complying with quality management systems such as ISO 9000 and HACCP and regulatory prescriptions, the suppliers' integrity is largely ensured. The use of the correct closure lining is extremely important mainly to restrict the oxygen permeability. Compared to natural and synthetic corks, screwcaps have the lowest oxygen permeability by far.

All screwcaps are not compatible with all glass bottles and vice versa. It is of critical importance for the neck diameter of the bottle to be compatible with the closure and capping machine. One of the problems in this regard is that bottle and closure suppliers do not communicate well with each other. Before and during bottling different inspections must take place to ensure successful bottle closure. Screwcaps are usually supplied in carton containers and care must be taken that neither the containers nor the plastic bags in which they are packed, are damaged. Damaged cartons may result in the distortion of closures and open bags may cause dust and other undesirable matter to end up in the wine. Care should be taken that the bottles to be used have the correct neck specifications.

Alignment of the equipment that twists the screwcap onto the bottle is critical. The application of the screwcap is a complex process and users must ensure that it is employed correctly. The fill height for bottles with screwcaps is extremely important to normalise the pressure in the bottle on the one hand, and to limit oxygen exposure on the other hand. In general 2% of the wine volume in the bottle was used as a safe calculation for the fill height. The possible uptake of oxygen is determined by the fill space and permeability by the screwcap. The former may be limited by using carbon dioxide, nitrogen gas or liquid oxygen to displace the oxygen. After bottling, cartons should not be stacked higher than three pallets, to limit unnecessary pressure on the screwcaps. Most suppliers of screwcaps also recommend that the torque required to remove a screwcap be tested regularly. It is equally important to test the tightness of the seal regularly (Work, 2005).

Cellars have been debating the problems surrounding cork closures for many years. As a result, various alternative products have been devised. Despite these alternative products, cork closures in different guises are still being used in all wine producing countries and cork suppliers have also launched innovative actions to improve their products. As a product, screwcaps have been subject to ongoing evaluation.

New Zealand can undoubtedly be regarded as the birthplace and home of screwcaps for wines. In less than 4 years it became the standard bottle closure for wine. Local critics of screwcaps contend that wines with such a closure display more sulphury flavours, while other panels claimed the exact opposite. It is not commonly known whether screwcaps also allow oxygen to come into contact with the wine, although this occurs to a considerably lesser extent than with natural cork (Tudor, 2005).

Advocates of screwcaps contend that the elimination of cork taint and unpredictable oxidation in wines that were thus bottled, has made screwcaps the standard closure for wines against which all other closures should be measured (Jalfon, 2005).

References:

Hawkes, G. 2005. The Screwcap Initiative. Vineyard & Winery Management. July/August 2005: 44 - 50.

Jalfon, J. 2005. Screwcap pioneer poses questions. Australian & New Zealand Grapegrower & Winemaker. March 2005: 82.

Phillips, C. 2005. The Science of Closures. Wine Business Monthly. September 2005: 16 - 23.

Tudor, P. 2005. Is This The Closure For Your Wine? Wine Business Monthly. July 2005: 16 - 24.

Work, H. 2005. Bottling Under Screwcaps. Quality control issues for premium wines. Practical Winery and Vineyard 27 (3): 33 - 48.

Prevention of fires in underground cellars

As a result of the fact that in the past, these cellars served mainly to store barrels, fire prevention in such cellars was never a priority as far as the owners were concerned. Underground cellars are currently being used for visitor routes, wine tastings, banquets and music concerts. In addition to production personnel, hundreds of members of the general public visit such cellars and apart from the barrels, ornamental decorations, lighting and even candles may form part of the cellar furniture. It therefore became necessary to pay professional attention to the fire hazard in underground wine cellars.

Local authorities were initially reluctant to draw up specific and appropriate guidelines for such cellars and the California Fire Code (CFC) was only developed in California in 1998. In terms thereof underground wine cellars fall into one of the following categories:

- Cellars that are used to store barrels only.
- Cellars that are used for tastings and guided tours involving a limited number of visitors and
- Cellars that are used for a large number of visitors.

The fire protection and life safety standards obviously increase in line with the potential threats. Although specific prevention prescriptions do not apply to underground wine cellars, Californian cellars took the initiative to assume responsibility and initiated specific actions. The three most important aspects requiring attention are the means of escape, fire detection and alarm systems and fire suppression systems.

One of the core principles of ensuring a safe escape route should a fire occur in an underground cellar, is to provide two exits regardless of the size of the cellar, so as to ensure that an alternative exists should one exit be blocked by a fire. Exit signs are essential, as are illuminated emergency exit signs.

The fire detection and alarm systems in cellars serve various purposes. The primary goal is the timeous detection of a fire and conveying this eventuality to the people inside the cellar so that the necessary evacuation may take place. A smoke detection system will most probably allow more time for the evacuation of the cellar. Fire alarm systems can also be linked to internal responsible persons or departments or even to the local fire authority in order to ensure that the fire fighting action is initiated as quickly as possible.

The installation of automatic sprinkler systems should be considered in the case of other equipment besides barrels, for example furniture and lighting, being found in cellars. The activation of the sprinkler systems may also serve as an immediate notification to initiate fire fighting actions (Domnitsch, 2006).

In South Africa fire prevention in cellars is regulated by the Occupational Health and Safety Act, number 85 of 1993.

In traditional wine countries underground cellars formed part of the production complexes for various reasons. In addition to the practical motivations, they contribute greatly to the mystique of wine. As a result, all wine countries ended up having underground wine cellars, even though other methods were available to create conditions similar to those in underground cellars. Consequently underground cellars have increasingly become more than simply being a part of the production process; they contribute to the promotion and marketing process of wine and brandy.

In terms thereof specific prescriptions apply concerning regulations that must be adhered to so that the evacuation of a building in the event of a fire may be facilitated, for example the type of doors used for emergency exits, the physical characteristics of stairs and the requirement of at least two exits per building. The prescriptions for fire prevention equipment and relevant actions are determined by the local authorities (Occupational Health and Safety Act & Regulations, 2001).

References:

Domnitsch, Cheryl, L. 2006. Fire Safety in Wine Caves. Wine Business Monthly August 2006: 68 - 71.

Occupational Health and Safety Act & Regulations. Act 85 of 1993. JUTA Law. Lansdowne. Updated 2001. www.winebusiness.com, search "Cave".

The impact of refrigeration on the energy bills of wine cellars

Estimates show than 50% of Australian wineries' electricity bill is allocated to refrigeration. By minimising cooling requirements and optimising the effectiveness of the refrigeration system, this percentage may be reduced. There are different ways of achieving this.

Most wineries use cooling in the settling process of grape juice for pre-fermentation clarification. Good sanitation practices, effective pH and sulphur dioxide management, timeous racking after settling and the possible use of centrifugation, flotation or cross flow filtration may reduce refrigeration cost for the process. It goes without saying that the purchase of equipment has to be acceptable from a quality and cost point of view.

It is generally accepted that low temperatures during the vinification process limit spoilage and improve the retention of desirable wine flavours. The question arises, however, whether the chilling temperatures might not be excessive. Excessive chilling may be caused, inter alia, by inadequate temperature settings, incorrectly calibrated temperature sensors or dirt in automatically controlled solenoid valves.

Although cooling is commonly used for tartaric stabilisation of wines, it may be applied much more effectively by using it in conjunction with agitators, heat exchangers and tartaric acid dosage.

The adaptation or design of cooling systems in existing or new cellars should always be undertaken by an experienced refrigeration engineer. The planning process should include a variety of decisions for which the necessary expertise is a prerequisite. Refrigeration is a specialist field that covers various disciplines from design to maintenance of refrigeration equipment.

Apart from the design and extent of refrigeration, the effective application thereof may be determined by various factors. Sufficient isolation of the specific equipment is essential and should focus not only on the macro components such as tanks and pipelines, without paying the necessary attention to bolts, clamps and valves. The design of the cooling jackets influences the thermal currents inside the jackets and this, combined with stirring the contents of the tank, may result in improved heat exchange. In a similar way the distance between the cooling plant and the tank stores, the tank store design, exposure to sun and wind, tank colour and the placement of the store vis á vis exposure to sunlight may have a big influence of the effective utilisation of the available cooling. The cross flow of pre-chilled media or products compared to that which still has to be chilled by means of heat exchangers may also result in considerable savings.

Each winery has a unique set of cooling facilities as a result of the different winery requirements and winemakers should not adapt or change the refrigeration systems of their cellars without the input of experienced refrigeration engineers or contractors.

Energy together with personnel accounts for the biggest operational budget of wineries. In order to be cost and therefore price competitive, it is essential for wineries to ensure effective and optimal functioning and use of refrigeration facilities. Daily checking to ensure that a refrigeration system is used optimally may ensure that contractors are not called out unnecessarily to solve what might be a simple problem, but if the necessary expertise does not exist, it is better for the cellar to prevent possible problems well in advance, rather than wait for the problem to manifest itself.

There is, however, a check list to ensure the effective operation of winery cooling facilities and considerable savings may be achieved if the check list is consulted regularly.

As the cost of electricity is usually cheaper outside peak periods, this may be exploited through careful planning. For white wine fermentation, for example, the switching on or off temperatures of the cooling system may be different for peak and off-peak periods, without reducing the effect of the cooling (Semmler, 2005).

References:

Day, C. 2005. The contribution of refrigeration processes to winery sustainability. Wine Industry Journal 20 (4): 63 - 65.
Semmler, B. 2005. Improving winery refrigeration efficiency for small to medium wineries. Wine Industry Journal 20 (4): 57 - 58.

A guide to energy efficiency is available from www.industry.gov.au/energybestpractice (Day, 2005).

Mourvèdre blends

Spanish in origin, this cultivar, also known as Monastrell or Mataro, is a vigorous grower that ripens late and has specific preferences with regard to climate, locality, plant material and viticultural practices. An old saying goes: "Mourvèdre needs its feet in water, head up in the sun and to see the sea" but although there is much truth in this, it should be interpreted using common sense. The right balance between sunshine, rainfall and humidity is of critical importance as it prefers a specific microclimate, proximity to water, high altitude and soil composition. Mourvèdre wines are often described as reductive and have specific tannin characteristics requiring specific phenolic ripeness.

In Europe it flourishes in specific regions near the Mediterranean, although it is often described as a Rhône cultivar. The original home of the cultivar is the regions Murcia and Valencia in the east of Spain. It plays an important role in the Alicante Jumilla regions of origin, where it occurs on sandy loam and limestone soils at heights ranging from 480 to 960 m about 80 km from the ocean. The average annual rainfall is 300 mm with an average annual temperature of 17°C. In the Bandol region of origin between Toulon and Marseilles with an annual rainfall of 560 to 660 mm, where cold Mistral winds often prevail, all AOC red wines should contain at least 50% Mourvèdre. The general belief there is that the cultivar requires a lot of sunshine for ripening, but suffers when it becomes very dry and hot. Although it is often considered a Rhône cultivar, it occupies only 1 to 2% of the plantings in Côtes du Rhône and 6% of the well-known Châteauneuf-du-Pape. The latter is considered to be the northernmost area for successful ripening.

In California it occurs to a limited extent with a total surface of only 829 acres in 2004, although it has been evaluated from 1984 onwards. One of the reasons for the limited occurrence is that suitable localities had been planted to more popular cultivars. The general preference, however, is for relatively cool sites with clay limestone soils to ensure late ripening.

Although also limited, the majority of Mourvèdre vineyards in Australia occur in the warm Barossa region. The d'Arenberg winery in McLarenvale near Adelaide is one of the pioneers as regards GSM blends or Mourvèdre per se. The most suitable vineyards are situated against hill slopes with clay and ironstone or limestone soils about 14 km from the ocean where excessive vigour is restricted and small berries are obtained.

Charles Back of Fairview is deemed to be the South African pioneer of Mourvèdre and has already planted 34ha to this cultivar. Most of the vineyards occur in Malmesbury near the ocean at heights of 370m where the changes in temperature promote good ripening.

There are different clones, viz. numbers 1069, 369, 247, 249 and a Davis clone, and the style of the wine is influenced more by the clone than by vinification practices. The general opinion is that bush vines produce the best results, although properly managed trellised vines may also be successful.

In recent years acronyms have become part of common parlance, also in the wine industry. One such is GMS or rather the blend of Grenache, Mourvèdre and Shiraz. Except for France where it has long been prevalent, it has also attracted the interest of winemakers in various new world wine countries. Mourvèdre plays a very important role in these blends.

The question is often asked whether it would be better to market Mourvèdre as a cultivar or as a blend. As a cultivar it has very prominent mulberry and blackberry flavours and may also be high in fixed acids and tannins. It therefore has characteristics that are acceptable on its own or in blends. Grenache may also contribute more fruit and the softness of Shiraz may also be complementary (James, 2006).

In South Africa it occurs mostly in Stellenbosch (19%), Paarl (33%) and Malmesbury (35%) and the total surface has increased by 78% from 2003 to 2005 (Sawis, 2007).

Only one French clone, MT 11, is currently available in South Africa, but new clones were imported from Australia in 2005 and are currently being propagated. The temperatures during ripening, especially the minimum temperatures, must be high to obtain sufficient sugar levels and it is therefore more suitable for the warmer areas (Visser, 2007).

References:

James, Richard. 2006. Understanding Mourvèdre. Wine Business Monthly August 2006: 30 - 34.
Sawis. 2007. Personal communication.
Visser, Charles. 2007. Personal communication.

The role of oxygen in vinification

In the case of humans oxygen is indispensable, but in vinification this wonderful guest can be either friend or foe. Oxygen is found all around us, however, and winemakers should therefore be aware that the role of oxygen in the handling of juice differs entirely from that of vinified wines.

Most of the facts regarding the role of oxygen in vinification are not new, but often these are either forgotten or otherwise winemakers do not adapt their practices to take them into account. The following facts regarding the role of oxygen in the wine cellar are supposed to be well-known:

- Lees may be used as protection against oxidation, but only to the extent that the available oxygen may be neutralised by the lees.
- The uptake of oxygen benefits from lower temperatures. A decrease of 5°C increases the oxygen solubility by 10%. Do take care when oxidising cold wines.
- The rate of alcoholic fermentation is increased by the exposure of the juice to additional oxygen.
- The formation of volatile acid during fermentation is mostly caused by a lack of oxygen for the yeasts, thereby putting stress on the latter.
- By properly managing the application of oxygen during fermentation, it is possible to obtain fruitier wines that are also able to remain fruity for a longer period.
- The racking of juice during the fermentation of red wine does not add any additional oxygen to the crushed grapes, seeing that it is saturated with carbon dioxide.
- If oxygen is applied for 1 second at a pressure of 3 bars to 100 litres of wine, it will be equivalent to 1 mg/l dissolved oxygen.
- If wines with a light colour, low tannins and a high pH are treated with micro-oxygenation, the process should be managed cautiously.
- Micro-oxygenation, like other vinification practices, is not a magic formula with which wines can be improved.

During the maturation of wines and the eventual bottling thereof, many practices and factors may contribute to the oxygen status of the wine. The following facts should always be borne in mind in this regard:

- Oxygen may react with phenols, resulting in the formation of hydrogen peroxide. The latter may react with alcohol, which may be converted to acetaldehyde. (Acetaldehyde is defined as an oxidation product and is reminiscent of an apple character.)
- Sulphur dioxide as an anti-oxidant does not react directly with oxygen, but rather with the oxidation products such as acetaldehyde. (Sulphur dioxide therefore eliminates the perceptibility of oxidation products.)
- The racking of wine from one tank to the next may result in an increase of 0.1 to 0.2 mg/l dissolved oxygen.
- The aeration of a still wine may result in an increase of 7 mg/l dissolved oxygen.
- Ordinary handling and maturation in barrels may result in an increase of 26 mg/l dissolved oxygen.
- The aeration of wines that have a rotten egg smell is not necessarily the best solution, since sulphites may be converted to mercaptans, which may in turn lead to disulphites. It is practically impossible to get rid of the latter.
- The measurement of dissolved oxygen depends on the position of sampling. The closer the sample to the surface of the wine, the higher the dissolved oxygen quality.
- In order to limit the oxygen uptake during maturation, maintain the cellar temperature between 14 and 18°C and the humidity between 60 and 70%.
- If the relative humidity during maturation is below 60%, water will evaporate from the barrels and the alcohol quality of the wine will increase. If relative humidity is above 60%, the alcohol will evaporate. In both instances an air bubble and vacuum will be created inside the barrels.

Micro-oxygenation (MOX) has become standard practice at many cellars, but the question is often asked why it is applied.

- It is possible to produce wine with a better structure and possibly use less sulphur dioxide.
- With micro-oxygenation the texture of the wine will be characterised by different phases. This cycle may be described as green, hard, firm, soft, full-bodied, complex and once again green. It is best to bottle the wine during the firm-soft phase.
- A so-called MOX recipe for a wine with maturation potential may be summarised as follows: Apply 60 ml oxygen / litre wine / month after wine has fermented dry and gradually reduce it to no oxygen just before the completion of MLF. Once the sulphur dioxide adjustment of the wine has been done, the dose may be increased for two weeks to 40 ml / litres / month and then again gradually reduced to 5 ml / litres / months before being pumped over to the maturation barrels.

MOX is a technique for managing the style of the wine so that when it comes to bottling, it will be unique to the particular cellar or winemaker.

Reference:

Crowe, A. 2007. The Role of Oxygen in Winemaking. Wine Business Monthly. February 2007: 85 - 86.

Reductive vinification

The trend to produce fruity wines induced winemakers to adopt extreme approaches in various respects. Grapes must be picked with a higher sugar content, inter alia, obviously resulting in a higher alcohol content. Despite their preference for fruitiness, consumers may object to the higher alcohol content. The higher alcohol content of wines could also cause problems with alcoholic or malolactic fermentation. Lower fermentation temperatures will result in the retention of more flavour in wine, but on the other hand complexity will be enhanced by higher fermentation temperatures. The use of different skin contact practices or different wood products will likewise result in different flavour profiles. The required balance between the different extremes will therefore have to be maintained in order to obtain the desired results. From one point of view, reductive vinification is an extreme approach.

Traditionally the vinification process has always been oxidative. The arrival of stainless steel tanks, the availability of inert gas, cooling, dry ice and other resources enabled winemakers to implement reductive vinification. The extent to which reductive vinification is applied, may be determined quantitatively by measuring the redox potential of the juice or wine. Although most wineries do not use redox potential measurements, it is common knowledge that practices such as racking, topping up, filtration and bottling cause the uptake of oxygen to a certain extent, which will increase the redox potential of the product. On the other hand the use of anti-oxidants such as sulphur dioxide, ascorbic acid and inert gases may reduce the redox potential of the product. Under controlled conditions oxygen can be beneficial, however. Macro-oxygenation is especially effective during alcoholic fermentation and also improves the colour stability and clarity of the wine. The tannins of red wines are also softened by controlled contact with oxygen.

While reductive vinification is a novelty in the wine industry, reductive processes have traditionally been noticeable in various wines. The bread or yeasty character of bottle fermented sparkling wine and the buttery tastes of Chardonnay that has been exposed to lees contact are typical examples, but in the present context reductive vinification is also linked to the pursuit of wines with more fruitiness. The presence of oxygen is limited, as far as possible, from the vineyard to the bottle; the result being fruit driven white and red wines. The use of cool cultivation areas, inert gas, low fermentation temperatures and specially selected yeast strains in particular has resulted in excessively fruity wines from New Zealand and Australia.

As with other extreme practices mentioned above, reductive vinification can also have detrimental consequences. A lack of oxygen in wine may result in the development of reduced sulphur compounds. Hydrogen sulphide (rotten egg smell), mercaptans or tiols (cabbage or burnt rubber smells) and disulphides (boiled wheat or canned tomato flavours) are the best known sulphide compounds. A consumer who expects a spicy Gewürztraminer or grassy Sauvignon blanc will definitely not be impressed by the above-mentioned sulphur compounds when opening the bottle. During the vinification process sulphides are usually first observed during alcoholic fermentation. This is generally the result of a nitrogen deficit in the juice which may be prevented by the addition of yeast nutrients such as diammonium phosphate, yeast cell walls and ammonium salts. The use of sulphur powder in vineyards is another possible source of hydrogen sulphide in wines. It is common practice in wineries to aerate wine if hydrogen sulphide is detected, but this is merely an apparent solution seeing that the mercaptans causing the smell are converted to disulphides, that are later split by free sulphur dioxide only to be detected once again as an off-odour. The best solution if hydrogen sulphide is detected, is to treat it immediately with copper instead, thereby removing the sulphur compounds. Preventative practices such as aeration during fermentation, the addition of sufficient yeast nutrients and regular sensorial evaluation of the lees are still the best option.

It goes without saying that oxygen, being one of the most important natural atmospheric gases, plays a very significant role in vinification. This role could be either beneficial or detrimental, depending on the stage or process of vinification. The winemaker decides whether an oxidative or reductive approach is to be followed. The oxidative approach allows normal exposure to oxygen, while the reductive approach tries to prevent or eliminate oxygen contact. However, it is also possible to adopt a golden mean or compromise using a different strategy at various stages. The decisions taken by the winemaker, whatever they may be, will have a marked influence on the style and quality of the wine.

One suspects reductively vinified wines that are bottled using metal closures to be more prone to the potential formation of undesirable sulphur compounds. It is speculated that the free sulphur dioxide content in such bottles is likely to remain higher than in bottles that have been sealed with synthetic or natural corks. The free sulphur dioxide may then break up the disulphides occurring in the wine, releasing them as off-odours.

Winemakers should decide therefore to which extent reductive vinification is to be applied, while being aware of the possible consequences of their decision(s).

Reference:

Cutler, L. 2006. Achieving Balance in Reductive Winemaking. Wine Business Monthly. October 2006: 24 - 27.

Oxygen ingress during bottling and storage

Oxygen ingress exerts considerable influence on the sensorial qualities of wine. The so-called fruit-driven wines that have become so popular in certain markets in recent years are particularly exposed to the negative effect of unnecessary oxygen ingress.

In wines that are stored in an upright position, the ingress and impact of oxygen may be summarised as follows:

- Movement through or around the bottle closure.
- Diffusion of oxygen to the wine.
- Dissolvement in the wine.
- Diffusion through the wine to the reaction core.
- Reaction with a wine component.

Various factors influence the above-mentioned movements. The movement through or around the bottle closure may be the result of a closure per se that is not tight, or contact surface with the bottle that is not tight. Both problems are exacerbated by vacuum bottling where the pressure outside the closure is higher than the pressure inside the bottle.

Increased temperature also promotes the mobility of the oxygen molecules. In order to prevent potential problems, the suppliers of bottle closures and winemakers should have the necessary equipment to evaluate the oxygen permeability of bottle closures on the one hand, while on the other hand winemakers should monitor the oxygen status of wines throughout the production chain (O'Brien, 2007).

The amount of oxygen and the tempo of ingress determine the extent to which the wine component that reacts to it, will change and therefore influence the sensorial qualities of the wine. Oxygen in the wine may increase during or after bottling by means of oxygen that is present in the filling cavity, oxygen ingress during the filling process and oxygen entering the wine through the bottle closure during storage.

All bottle closures in a particular closure group such as corks, screw caps, plastic closures, metal closures and closure linings do not necessarily react the same. For example, the characteristics of screw cap linings such as Saranex and tin vary considerably and the elasticity of many natural and synthetic corks after closure of the bottle is unpredictable.

It is also interesting that the most common bottle closure problems in the wine industry will never be acceptable in any other liquor industry.

The term Total Oxygen Pickup (TOP) is commonly used in the food and liquor industries to monitor the oxygen ingress during the filling process and subsequent storage. In the case of bottling this includes oxygen ingress in the bottling tank, wine hoses, turbulence in the filling reservoir, the exposure of wine to air during the filling process, air in the bottle filling cavity and migration through the packaging.

It is usually measured in parts per million (ppm) or parts per billion (ppb). It may be monitored by measuring the dissolved oxygen quality at different stages in the course of the filling process. The basic stages that should be measured, are the bottling tank outlet, bottles that have just been filled and those that have just been sealed. The sampling may be extended to the top of the bottling tank, filter and filling machine to ensure more comprehensive monitoring.

As may be expected, oxygen ingress in wines that have been bottled with screwcaps is considerably less than in those with natural or synthetic cork closures. There is not a marked difference, however, in the oxygen ingress in wines that have been bottled with natural or synthetic corks.

Ways of limiting oxygen ingress in wine during bottling will be discussed in a subsequent article.

Wine chain logistics extend from the vineyard to the bottle of wine that is purchased by the consumer. Viticulturists and winemakers go to great lengths to ensure that the grapes are received at the cellar at optimal ripeness; moreover, vinification processes are applied and managed in such a way that the quality of the final product is above suspicion. It often happens, however, that the bottling and packaging processes of the wine are handled by another party such as a mobile bottler or another division at large companies. It is extremely important for activities such as these to be executed with the greatest possible care to maintain the level of dedication that formed an initial part of the logistics chain. The possibility of oxygen ingress during bottling is one of the greatest sources of quality problems.

References:

Crochiere, G.K. 2007. Measuring oxygen ingress during bottling/storage. Practical Winemaking, January/February 2007: 74 - 84.

O'Brien, V. 2007. Oxygen ingress: Things to consider. Australian & New Zealand Grapegrower & Winemaker, March 2007: 75.

The prevention of oxygen uptake during bottling

If the bottling process is divided into the usual sequence of activities, the relevant actions to be initiated or applied may be summarised as follows:

Bottling tank
If bottling tanks are not filled to capacity, which is not supposed to happen, the space should be filled with inert gas. It will also be expedient to sparge inert gas through the wine even if the tanks are full. The use of argon or nitrogen as inert gases is recommended, in view of the fact that carbon dioxide is soluble in wine and may impart pétillance to the wine.

Wine hoses
The length of the hoses should be limited and any unnecessary coupling links avoided. Ensure that the hoses and coupling links are in good condition without any leakages. The hoses should preferably be de-aerated with inert gas before the wine is racked.

Filter
Ensure that all filter connections have a tight seal and that air spaces are filled before wine is pumped through the filter.

Filling machine
Use vacuum filling machines if oxygen uptake during bottling has to be limited. Before the wine is pumped into the filling machine, oxygen pockets should be prevented by rinsing the filling machine with inert gas. The filling heights should be optimised and care taken that the desired filling heights are maintained in all bottles.

Pre-evacuation of the bottles
Bottles should be de-aerated with inert gas and a double evacuation of bottles with inert gas is even better.

Determination of oxygen in bottles
It is important to determine the oxygen levels in newly filled bottles to ensure that the preventative actions were successful.

Evacuation or rinsing of the filling space of bottles
Vacuum closure of bottles is beneficial provided its implementation is effective. The filling space should obviously be restricted to the minimum. Rinsing with inert gas apparently has limited advantages and the injection of liquid nitrogen is the most effective method.

Rinsing the closures
By rinsing the inside of hollow closures such as screw caps with inert gas before closure, oxygen uptake in the wine may be restricted.

The dissolved oxygen content in the bottle after bottling should ideally be less than 1 mg/l. Bearing in mind an uptake of 0.1 to 0.2 mg/l oxygen during the transfer of wine between tanks, it is obvious that the above-mentioned ideal scenario can only be achieved if the respective actions are executed with the greatest possible accuracy. All actions should be carefully monitored, because a few mistakes could spoil the entire operation.

Closed bottle
Once the bottling and closing processes have been completed, oxygen analyses of the wine and filling space should be conducted to determine the oxygen uptake.

Reference:
Crochiere, G.K. 2007. Practical Winemaking, January/February 2007: 74 - 84.

The impact of wine cellars on global warming

Global warming occurs as a result of gases such as carbon dioxide and methane that are released into the atmosphere, thereby increasing atmospheric temperature. Industry has to shoulder the blame, but our daily lives are also responsible, whether the impact is direct or indirect. In the USA 21% of carbon dioxide pollution, for example, occurs as a result of actions that have to be taken to supply the domestic energy consumption. Emission gases of motor vehicles also contribute to global warming and cars differ in their contribution to the release of global warming gases. A well-known car such as a 2006 C230 manual Mercedes Benz "produces" 4.268 tons of carbon dioxide if it clocks 20 000 km per annum (www.lenntech.com).

A recent UN report predicted the following shocking consequences if global warming should continue:

- Food shortages for 130 million people by 2050.
- Drought and higher sea levels in Australia and New Zealand by 2030.
- Threatened survival of eco-rich sites such as the Great Barrier Reef.
- Approximately 100 million people will be exposed to oceanic floods each year, if the sea level rises by 1 to 3 mm annually.
- Veld fires and heat waves will occur with greater frequency.
- Coral reefs and fishing will undergo drastic changes (www.livescience.com).

These statistics appear to be far removed from the wine industry, but closer investigation reveals shocking facts. Temperature increases have obvious implications for cultivar suitability and viticultural practices, but it is not the purpose of this article to deal with such matters.

Wine cellars are already and will be held more and more accountable for their environmental standards. The cultivation of grapes and subsequent vinification use considerable resources such as water, electricity, fuel, chemicals and vehicles and consumers increasingly question the impact thereof and of the so-called "food miles", the distance from the cellar to the consumer, on the environment. A recent report by the British Department for Environmental, Food and Rural Affairs calculated that the "food miles" increased by 15% between 1992 and 2002. Supermarket groups are urged to buy from so-called "carbon neutral" suppliers (The Age, 2007).

Just such a "Carbon Neutral" programme was initiated in Australia in 2001 and producers and wine cellars were requested to plant specially selected plants so as to neutralise the influence of the global warming gases that had been emitted (Corsey, 2007).

Backsberg Estate, which recently acquired carbon dioxide neutral status, has an emission of 1 590 tons of carbon dioxide annually to the atmosphere as a result of its activities. This was calculated taking into account the energy consumption on the estate, wine fermentation, transportation of products, marketing trips, transport of packaging material and other resources. To neutralise the influence of these carbon dioxide emissions, one tree will be planted for each 2 tons of emitted carbon dioxide (Nellie Brand, 2007).

"Unchecked climate change will be an environmental and economic catastrophy, but above all it will be a human tragedy. It is absolutely vital that international action is taken now to avoid dangerous climate change."

Achim Steiner, Executive Director of the UN Environment Programme

The alcoholic fermentation process of wine obviously has a significant influence on the release of carbon dioxide into the atmosphere, seeing that carbon dioxide is one of the natural by-products of the process. The extent thereof in South Africa only becomes apparent when the following calculations are done:

The alcoholic fermentation process is formulated as follows by the Gay Lussac formula of 1810:

1 Molecule Glucose or Fructose > 2 Molecules Ethanol + 2 Molecules Carbon dioxide + Energy – 180g Glucose or Fructose will theoretically produce 88g Carbon dioxide.

The relationship between °Balling and actual sugar content in g/litre can be obtained from tables and 20°B for example is the equivalent of 191g sugar/litre.

- If one ton of grapes is pressed at a sugar content of 22°B and 750 litres of juice thus recovered, ca 79kg of carbon dioxide are formed during the alcoholic fermentation process.
- If the South African industry produces 710 million litres of drinkwine, 82 million litres of wine for brandy and 150 million litres of distilling wine at an average alcohol content of 12% A/V per annum, ca 94 000 tons of carbon dioxide will be formed annually during the alcoholic fermentation (Sawis statistics, 2007).

One could argue that the consumption of carbon dioxide by the vines during photosynthesis theoretically neutralises this formation of carbon dioxide, but it is doubtful whether this is likely to be achieved in practice (The Age, 2007).

The above facts are not intended as a threat or a warning, but rather to raise awareness among wineries about this topic. Actions that should receive attention from cellars, are the following:

- A planting programme of indigenous trees that could also contribute to the image of cellars. More or less five trees are required to neutralise the influence of one ton of car-

bon dioxide. There are, however, differences of opinion as to the number of trees to be planted per ton of carbon dioxide.

- An optimal cellar waste management programme.
- The use of cold air outside the cellar in cooling systems.
- The reduced use of plastic.
- The use of thinner glass bottles and consequently smaller cartons thus implying more bottles per export container.
- The more effective and economical consumption of electricity in the cellar.
- The use of energy saving bulbs.
- The more frugal use of fuel during the transport of the grapes to the cellar.
- The possible use of biofuel.
- The use of more environmentally friendly sources of electricity such as solar power where applicable.

Discussions are currently under way to investigate the establishment of a South African wine industry "Carbon Neutral" programme.

References:

- Brand, Nellie. 2007. Backsberg se bome help vergoed vir CO_2. Sake 24, Friday, 30 March 2007.
- Corsey, Lauren. 2007. Carbon neutrality creating a rejuvenated landscape. Austr Viticulture, March/April 2007: 62 - 63.
- Sawis statistics. 2007. Personal communication.
- The Age, Australia. 2007. Red, white and green, 27 February 2007.
- www.lenntech.com.
- www.livescience.com.

The use of mannoproteins for the tartrate stabilisation of wine

The concentration of potassium bitartrate (cream of tartar) in unstabilised wines always exceeds that which is practically soluble, especially if the wine is chilled. Higher alcohol content and lower temperatures promote the natural precipitation of the crystals. However, it may take a fair amount of time for the oversaturated tartrates to be precipitated from the wine and consequently cellars prefer to accelerate the natural process.

The traditional method of tartrate stabilisation involves promoting the precipitation of cream of tartar by storing the wine for a certain period at a temperature just above the freezing point of the wine. This creates an oversaturated wine solution and the excess cream of tartar will be precipitated as crystals. The precipitation process does not take place, however, unless certain favourable conditions are created. The precipitation process entails two phases, i.e. firstly the formation of a crystal nucleus that initiates and promotes the precipitation process, and secondly the formation of sufficient crystal around the nucleus to induce precipitation. By simply relying on reduced temperature to enable these processes to take place, it may take too long and therefore it is often promoted by the addition of fine tartaric acid crystals that are used as a nucleus for the crystal growth process. However, the cold stabilisation of wines to prevent tartaric instability has several disadvantages:

- The energy cost is high.
- Considerable infrastructure is required and the maintenance thereof is expensive.
- It is time-consuming and requires a great deal of manpower.
- The chemical composition of the wine is altered due to potassium bitartrate (cream of tartar) being removed from the wine.

Despite the above disadvantages, tartrate stabilisation of wine is essential from a consumer point of view. Any alternative method of tartrate stabilisation should therefore address the processes of tartrate precipitation, i.e. the formation of crystal nuclei and crystal growth.

It has been noted that wines which mature on the lees have greater tartaric stability. This is the result of the mannoproteins released during yeast autolysis. Research on model wine solutions has proved that mannoproteins inhibit the crystallisation of potassium bitartrate. These react as a protective colloid which covers the surface of the crystal nucleus used for the crystallisation and the crystallisation process is therefore unable to proceed. As a result Laffort Oenologie has developed a purified mannoprotein product, known as Mannostab, for tartrate stabilisation of wine. The product is soluble and has no colour, flavour or taste. Use thereof has already been sanctioned in the European Union and Argentina and is currently also being investigated for permissibility in Australia and the USA. (In South Africa it is not yet permissible.) Mannostab must be added to the wine

Tartrate crystals that occur naturally in chilled unstabilised wine, create an unacceptable perception among consumers due to the visual impact of the crystals. Tartrate stabilisation of packaged wine is therefore essential so that consumers are not unnecessarily upset by the possible occurrence of crystals in wine.

the day before bottling at a dosage of 200 to 250mg/l and good mixing is obviously important.

The use of mannoproteins should not be confused with meta-tartaric acid. The latter is a polymer of tartaric acid that is able to create temporary tartrate stability in wines. Although it functions in a similar way to the mannoproteins, the meta-tartaric acid eventually hydrolises and long-term tartrate stability is not obtained.(Bowyer and Moine-Ledoux, 2007).

References:

Bowyer, P.K & V. Moine-Ledoux. 2007. Mannostab: the award-winning new potassium bitartrate stabilisation product. Austr & New Zealand Grapegrower & Winemaker. June 2007: 57 - 62.

The retention of flavour compounds in white wines

The oxidation of young white wines usually takes place in two stages. Firstly there is a transformation process of the flavour compounds, resulting in losses of the wine's unique flavour profiles. This goes hand in hand with the formation of other flavour compounds associated with maturation or taint. Secondly a browning process is observed. Wines contain many phenolic compounds, which, being anti-oxidants, are able to offer natural protection against oxidation. It has been reported, for example, that both caffeic and gallic acid are able to inhibit flavour degradation in white and red wines during oxidative storage. Amino acids and peptides also act as inhibitors to browning in a wide variety of food products. In this regard glutathione is one of the most active compounds.

In the wine industry sulphur dioxide is generally used as a preservative and an anti-oxidant, but above certain values it may impact negatively on flavour and some consumers also experience negative health effects such as asthma. As a consequence there is a general trend to keep the sulphur dioxide levels in wines as low as possible.

A project was launched in Greece to determine how the use of caffeic acid and/or glutathione, combined with sulphur dioxide influences the flavour concentrations of white wines during storage. A 2004 white wine made from Debina was used in the study. Debina is a late cultivar and the wines oxidise easily. The two different levels of sulphur dioxide used in the study were 35mg/l free and 143mg/l total, compared to 55mg/l free and 166mg/l total. Ascorbic acid at a concentration of 90mg/l was a standard addition to all the wines. The different caffeic acid and glutathione additions involved 60mg/l caffeic acid, 20mg/l glutathione and a combination of 30mg/l caffeic acid and 10mg/l glutathione respectively. Wines were stored at 20°C in a dark room for various periods of time.

Different flavour compounds were analysed at different stages. The findings of the project may be summarised as follows:

- Wine samples with the two different sulphur dioxide levels display similar concentrations of flavour compounds.
- Sulphur dioxide does not seem to play a cardinal role in the protection of flavour compounds during storage.
- The addition of caffeic acid and glutathione or combinations thereof prevents losses of several volatile esters and terpenes during the storage of wines with the lower sulphur dioxide content. This includes, amongst others, important esters such as isoamyl acetate, ethyl caproate, ethyl caprilate, ethyl caprate and linalol.
- The inhibiting effect of caffeic acid and glutathione on the loss of flavour compounds is most likely due to their anti-oxidant properties (Roussis et al, 2007).

Caffeic acid and glutathione are natural ingredients of wine. Caffeic acid's ester with tartaric acid, caphtaric acid, is predominant in grapes. With ripening of grapes and during fermentation glutathione increases to values of 2 to 5mg/l.

Wines from the so-called new world wine countries are well-known for and popular mostly because of their fruitiness. Loss of flavour in young white wines especially is therefore a source of concern for South African winemakers and different practices are being adopted to address the problem.

Presently in South Africa the addition of none of these components is allowed during vinification.

Reference:

Roussis, I.G., Lambropoulos, I. & P. Tzimas. 2007. Protection of Volatiles in a Wine with Low Sulfur Dioxide by Caffeic Acid or Glutathione. Am. J. Enol. Vitic. 58(2): 274 - 278.

“Wine in wood and wood in wine”

Series by:

Charl Theron, Special Guest Lecturer, Viticulture & Oenology
Tim Rypstra, Professor in Wood Science
Jan Swart, Director, Wood and Fibre Institutute

University of Stellenbosch

Recycling used wine barrels

The well-known impact of oak barrels on the production cost of wines may be blamed on several factors. Firstly the cost of the wood as raw material, the time required before the wood may be used and the time consuming labour during the composition and treatment of the barrels. Secondly the under-utilisation of the barrels' wood volume, seeing that only a few millimetres of the wood components on the inside of the dowels are extracted. The use of barrels as second or third fill barrels does not make a major difference. Thirdly, the apparent inability of cooperages to find a positive application for the unused wood volumes of used barrels.

Last year the Australian Co-operative Research Centre for Viticulture (CRCV) and Wine Industry Suppliers Association (WISA) held a workshop about innovation in oak flavourants and tannins. The following issues were identified as being the most important:

- The need for standards in the descriptive terminology of oak products.
- The willingness of wine cellars and wood suppliers to accept new technology.
- The impact of used barrels and alternative oak products on the environment.
- Problems experienced during the transport, handling and storage of barrels.
- The inadequate application of existing research and development information (Corsey, 2006).

The recycling of unused oak from used barrels is an innovative development initiated by the Australian body Ausvat. The first investigation took place seven years ago in South Australia and eventually resulted in a patented process that occurs in different stages:

- Used barrels are deconstructed by several wine cellars and the individual dowels transported in crates to the Ausvat plant. Particulars such as oak type, cooperage, barrel age and sanitation process accompany the consignment and the wood from different cellars is kept away from each other.
- The part of the dowels penetrated by wine, is removed from the remainder of the dowels by means of a sawing process. This waste product is taken to a garbage dump away from the premises.
- Subsequently the remainder of the dowels not influenced by wine is chopped into two battens and specified as being either inside or outside battens. These battens are shaved on both sides to expose the grain and cell structure of the wood. Possible areas of contamination, such as the ends of the battens, are also removed.
- The subsequent toasting process is preceded by a process whereby the battens that are still in the bent shape of barrels are placed on conveyor belts for toasting, using pressure and far infra red heating (FIR) to bend the battens into shape. FIR is also used to obtain various toasting levels and the heating also results in the sterilisation and homogenising of the wood.
- After toasting of the dowels they are stacked in bundles of 60, which is the equivalent of 8 square metres of wood surface. After leaving it for a few days to stabilise, it is finally packaged in plastic bags and may be stored for up to 6 months before being used.

By recycling the dowels of used barrels access to an enormous source of unused wood is gained, thereby ensuring the more effective use of the wood. Unlike the normal 2.1 square metres of wood surface of a 225 litre barrel, the available wood surface of the same wood volume is increased to 8 square metres. Environmental benefits are the clean oak shavings deriving from the process which may be used to make compost, which could be especially beneficial to organically grown grapes.

Well-known Australian wine cellars such as Penfolds, Rosemount, Lindemans, Wynns, Great Western and Devil's Lair are using it. French cooperages are also interested in the process and with the French having recently allowed the use of alternative wood products for vinification, the recycling of the wood from used barrels may be welcomed there too (Warren, 2006).

References:

Corsey, L. 2006. Wine Industry Journal 21(5): 38 - 39.
Warren, P. 2006. Australian & New Zealand Grapegrower & Winemaker July 2006: 61 - 62.

The use of American oak barrels

The difference between French and American oak has less to do with the geographic origin of the wood, than with the wood species with which each is associated. Even an amateur will notice the obvious difference in flavour and taste. American oak is often described as aggressive, dusty or one-dimensional, but even so it makes a unique contribution to well-known international wines. Winemakers often prefer to use a combination of French and American oak seeing that these two can be complementary. Due to the lower price of American oak, it is obvious why financial managers are partial to it.

During the 1990s many American wine cellars used American oak to ferment and mature white wines, and to mature red wines. Thereafter many cellars switched to alternative wood products in view of cost considerations. Nevertheless many cellars were still convinced of the uniqueness of American oak and capitalised on it. It occupies a specific niche area in the wood maturation of wines and is used for Cabernet Sauvignon, Zinfandel, Cabernet Franc and Chardonnay in particular.

As a result of its unique characteristics, it adds a specific dimension to wines. Cellars that do not simply want to be copy cats are given an alternative option by using American oak. It may impart a wide range of flavour profiles to wine, including the following:

- Vanilla
- Spice
- Sandalwood
- Cloves
- Coconut
- Tropical flavours
- Butter caramel

In order to ensure optimal use of the above-mentioned complementary characteristics, the cellars demand that American oak comply with the following specifications:

The percentage new barrel usage may vary from 30 to 60%. An air drying period of 24 to 36 months for the wood once it has been cut. Barrel toasting should always be medium plus to heavy. It should preferably be used in conjunction with French oak, as the American oak provides the outspoken flavours, while the French oak imparts more complexity.

The treatment of new barrels should not assume drastic proportions; it is recommended that a rinse with warm water upon receipt be followed by a simple cold water sealing action (Work, 2006).

Ever since 1971 Ridge Vineyards has been convinced of the special role played by American oak in their wines. The most important motivation was that they did not believe in making French style wines only; they wanted to develop a unique character instead. At that stage properly coopered American oak barrels were not readily available and they had to rely on the coopers of Bourbon whiskey barrels, who had matured American oak staves on hand. This also resulted in Ridge Vineyards insisting that all wood for their barrels be matured for at least 2 years. In addition to this requirement the cellar also evaluates different barrels and suppliers annually before making up different blends (Anonymous, 2006).

In South Africa, American oak barrels cost between R2 500 and R3 000 (excluding VAT) less for 225 and 300 litre barrels and these are used especially for wines requiring a more aggressive wood character. American oak usually imparts a wide variety of flavours such as coconut, vanilla, chocolate and spice to the wine. As a result of the prominent wood character with the accompanying flavours mentioned above, it is often used in conjunction with French oak barrels. If the particular flavours are intended to merely complement French oak barrels, different forms of alternative American oak products may be used in conjunction with the former. However, due to its aggressive flavours, complementary use thereof should be carefully managed.

References:

Anoniem. 2006. History of American Oak at Ridge Vineyards. Practical Winemaking November/December 2006: 28.
Work, H. 2006. American Oak Barrels. Find Their Niche. Practical Winemaking November/December 2006: 20 - 27.

The influence of oak on the vinification and maturation of wine

Although barrels were initially only intended to be a container for wine, it is general knowledge that the wood character thus imparted adds another dimension to wine. It is also true, however, that the wood character of a wine is not necessarily complementary, but might even be excessive or unbalanced. The source of the wood character will certainly also play a role. If a wine is matured in a barrel of recognised quality, it will differ markedly from the same wine to which alternative wood products had been added. In a similar way the maturation circumstances such as temperature and humidity will also important roles. The question arises therefore, exactly how positive is the role played by wood in the vinification process?

The English Institute of Wine Masters conducted a seminar on oak in 2005 in conjunction with the wine department at Christie's and the Taransaud cooperage. Five tastings were held of different 2004 French and American wines that had been matured, inter alia, in specially made 30 litre oak barrels with different variables, to evaluate the influence of the variables.

Fermentation in stainless steel, new or used barrels

Ramey Wine Cellars of Carneros, California, compared the influence of Chardonnay fermentation and maturation in new and used oak barrels as opposed to stainless steel containers. In addition they also investigated the influence of lees maturation and battonage. Their results may be summarised as follows:

The wine matured in stainless steel has the least flavour with delicate grapefruit and grassy flavours. Wine matured in the second fill was most reminiscent of a Burgundy style accentuated especially by its milky cheesy flavours and soft taste. The new barrels obviously imparted a marked wood character on the nose and taste and on the latter in particular it was the most complex of all the treatments.

French, Polish and American oak

Chateau Malartic Lagraviere of Bordeaux, France compared the influence of French, American and Polish oak barrels to the vinification of Sauvignon blanc in stainless steel. Wood maturation then took place in medium toasted barrels for 24 months. The results of that investigation may be summarised as follows:

- The wine made in stainless steel was thin with little colour and had a coarse lemon and lime character. The grassy character of the wine resulted in an unpleasant aftertaste.
- French oak maturation resulted in an integrated wine where the floral notes were complemented by the buttery oak character.
- American oak resulted in overwhelming cucumber flavours and although the taste was also smooth, the prominent caramel and baked spice flavours confirmed the origin of the oak.
- An unbalanced character was noticeable as regards the Polish barrels. Although caramel and spice flavours also occurred, the uniqueness of the oak, described by some of the tasters as cardamom, did not find favour.

The same cellar did the same comparison using red wine, but the tannins made the differences less obvious. The difference between the French and Polish wood in particular was more difficult to notice, but once again the aggression and cucumber flavours of the American oak were dominant.

Troncais, Vosges and Central French oak

Oak used for barrels may hail from Northern, Eastern or Central France. Oak from the cold eastern and northern parts usually belongs to the Quercus sessilis species and imparts more complexity to wines compared to the central Alliers and Troncais oak that result in a more spicy character and a better mouthfeel respectively in wines. Southern central Limousin oak imparts a more aggressive vanillin character to the wine.

Corton Charlemagne Grand Cru wine was matured extramurally in medium toasted barrels for 24 months and again compared to wine stored in stainless steel. Although the barrels from the cooler northern regions imparted more structure to the wine and the southern regions' barrels showed more prominent oak, the tasting results were not consistent and nuances were the only difference among the wines.

Influence of air drying

If wood is not sufficiently dried, the green tannins of the wood can be observed in the resultant wines. It is not only the period of drying that plays an important role, but also the means of drying. It is therefore recommended that when

buying cheaper barrels, made of wood that had been dried for a shorter period, a heavier toasting should rather be specified seeing that the green tannins will then be less noticeable in the wines. The drying of the wood is necessary to stabilise the wood before it is used for barrels. The moisture content of the freshly split wood therefore has to be reduced from 55 to 15%. The best quality barrels are made of wood that has been air dried for up to 4 years.

Red wine from Chateau Lagune and Sauvignon blanc from Chateau Malartic Lagraviere, also mentioned above, were matured in barrels made of wood that had been air dried for 24, 12 and 6 months respectively. In both instances the barrels that underwent drying for 6 months contributed least to the wines, those that underwent 12 months' drying showed the most tannin and wood character and the 24 months' drying resulted in the most complex wines with the best mouth-feel.

Toasting level

The toasting of wood develops flavours that are more or less noticeable sensorially depending on the intensity and duration of the toasting. The toasting levels may range from light or medium-minus, medium, medium-plus and heavy to intensive. Light toasting is for example at 120 - 180°C, medium toasting at 200°C and heavy toasting at 225°C.

A Sauvignon blanc/Sémillon blend from Domaine de Chevalier and a Merlot from Chateau d'Aiguilhe both in Bordeaux were exposed to no medium and heavy toasting compared to a stainless steel control. In both instances the heavily toasted barrels produced the most complex wines. The red wines showed no difference in colour, but the white wines were increasingly yellow with increased toasting. Untoasted wood produced a coarse, short taste in the wine. Although vanilla, caramel and clove flavours were noticeable in the medium toasted samples, heavy toasting resulted in the most prominent flavours and taste characteristics, as could be expected.

In the light of the different influences that the above factors have on the character of wine, winemakers and cellars will always differ about their preference for a specific wood character in their wines (Canterbury, 2006).

Reference:

Canterbury, C. 2006. Oak's Influence on Making and Maturing Wine. Wine Business Monthly December 2005: 34 - 37.

The use of oak in the vinification of flagship wines

Nowadays oak comes in so many formats, quality and prices to meet different quality and price category requirements that the question is often raised about which factors should be considered by winemakers before deciding which products to purchase in which format. It is often a process of experimentation before reaching a final decision, but due to the cost implications it is necessary to take that decision as soon as possible. In this article reference is made to Marsanne and Durif cultivar wines that are often unknown in South Africa.

Various Australian winemakers were requested to elaborate on their experiences with the use of oak in the vinification of flagship wines.

All Saints Estate, Rutherglen, Victoria

Family Cellar Marsanne

25% New French oak is used and the remainder consists of second fill or older barrels of different sizes. Whole bunches are pressed, spontaneous fermentation is allowed and the malolactic fermentation (MLF) occurs in the barrels, whereafter 20 months' maturation takes place, involving lees contact with monthly battonage. The cooperages of preferences are Rousseau, Sirugue and Vicard. Very slow maturation is preferred without the extraction of excessive wood character and there is consequently an ongoing shift to larger barrels such as puncheons. The bigger barrels ensure that the wine remains fruitier, despite lees contact of up to 2 years.

Family Cellar Durif

The wine is fermented in open barrels, left on the skins for at least 3 weeks, whereafter it is pressed and left to mature in wood for 2 years. The extended skin contact ensures stable tannins and the wine is racked once only towards the end of the first year. 30% New oak is used annually with a 60/40 ratio between French and American oak. The preference is for French oak from Rousseau and Vicard and American oak from AP John and Sequin Moreau. Larger barrels such as hogsheads and puncheons are increasingly popular to retain more fruit in the wine. Since Durif wines have a delicate, floral aroma, they are easily dominated by an excess of oak.

Landara Park, Fleurieu, South Australia

Landara Park Reserve Merlot

Prominent blackberry and violet flavours are desirable in this wine and it is therefore important that it should not be diminished by the use of wood. Depending on the particular vintage, different wood treatments may be preferred. The current availability of alternative oak products facilitates the decision as to which oak treatments should be used. The first release of this wine in 2005 was matured in 3-year-old American hogsheads for 15 to 18 months. As the vines become older, the wood treatment will also be adjusted. The 2006 vintage, for example, will be partially matured in 1 000 litre containers with staves and used barrels treated with the Ausvat method (see article "Recycling used wine barrels" in the March 2007 issue of WineLand). Before commencing wood maturation as soon as possible after alcoholic fermentation, the acid content is adjusted so that a pH of less than 3,5 after MLF is obtained in the barrels. The first racking occurs only after completion of MLF.

Stony Rise Wine Company, Tamar Valley, Tasmania

Holyman Chardonnay

This flagship wine is only made in quality vintages. Since a crisp Chardonnay character with a prominent citrus character is preferred, no MLF is allowed. 100% New medium toasted French oak is used for fermentation and maturation. Once the alcoholic fermentation has commenced, the juice is stirred every second day and after completion of the alcoholic fermentation, sulphur is added to the wine to prevent the onset of MLF. Battonage occurs on a weekly basis until the oak character becomes noticeable. Limited oak character is required, therefore 3 years' dried oak from various coopers is used.

Holyman Pinot noir

As with the Chardonnay mentioned above, the wine is made only in exceptional vintages. The grapes come from vineyards with a low yield (1,5 tons per hectare) that ripen early. The oak character should not predominate – consequently a low percentage of new oak is used. After skin contact the wine is matured in 20 to 25% new oak, 20 to 25% second fill barrels and the rest in 4-year-old barrels. In all instances 3 years' dried oak from various coopers is used. During the MLF in the barrels, the wine is stirred weekly and topped up regularly. Depending on the wine, it can remain on the MLF lees for a few months before being racked. It usually remains in the barrels for altogether 12 months.

Different cooperages are used to impart more dimensions to the wine. Both barriques and oxheads are used for both wines. The sanitation of the barrels is extremely important and barrels are usually used for 4 cycles only.

Reference:

Anoniem. 2006. Winemaker FORUM. Using oak in flagship wines. Australian & New Zealand Grapegrower & Winemaker: July 2006: 63 - 66.

The increasing use of alternative wood products

Alternative oak products such as staves, chips, shavings and powders were initially used in vinification mainly because of the cost benefits. In due course it has almost become standard practice at most wineries. This is mainly because the nature of the products enables precise management of specific characteristics such as toasting level with the accompanying flavour profiles; it is possible to use these alternatives from the crushing of the grapes to maturation; and provided the specifications are clearly prescribed, they are subject to less variation than wooden barrels. The use of micro-oxygenation adds a further dimension to the use of alternative oak products.

In a 2006 survey regarding the use of wood by North American wineries, research was conducted at different size cellars on the use of different forms of oak, the origin of the oak and the use of micro-oxygenation. The following interesting conclusions were reached:

- The percentage of wine matured in barrels has decreased. This is especially true of white wines, but the trend was also observed in red wines. This is mainly due to space saving of tanks in which alternative products are used, as opposed to barrels, the subsequent reduction in labour required and the creation of new wine styles where micro-oxygenation is used in conjunction with alternative oak products.
- The choice of French, American and Eastern European oak is largely determined by the characteristics imparted to wine, but while French oak still remains the most sought after, American oak retains its cost advantage and Eastern European oak elicits increasing interest.
- The use of alternative oak products has increased consistently since 2003. The use of alternatives seems to correlate directly with the decrease in the use of barrels. The use of alternative products made a wide range of oak flavour profiles available to winemakers, while enabling the sustainability of specific wine styles. Of the alternative products, oak chips and cubes remain the most popular format, with oak powder the third most important product.
- Micro-oxygenation (MOX) is being used increasingly by cellars. In addition to softening wine tannins, improving the colour stability of red wines, integrating wine flavours and reducing reductive flavours, MOX can also be used with alternative oak products as an alternative to barrel maturation. The reasons for using this method vary from cellar to cellar, the main reasons being cost and an alternative technique to create new wine styles (Pregler, 2006).

Alternative oak products range from fine powder to staves, with a variety of forms and sizes between the two extremes. The various products may be used at different stages in the course of the vinification process.

The addition thereof in the form of fine powder or chips, especially during red wine fermentation, has increased because it reduces the green tannin character of red wines, improves the colour stability and promotes the polymerisation of phenols and anthocyanins. The dosage ranges from 1 to 4 kg per ton of grapes and will also determine the extent to which oak character is imparted to the wine. With Chardonnay fermentations, staves are used mostly at a low dosage. Seeing that untoasted oak still contains oak tannins, which are reduced by toasting, it is logical to use untoasted products for colour stability. But as the tannin levels differ from one tree to the next, and are also leached out of the oak during ripening, the variation in tannin levels obliges winemakers to use toasted products instead.

In recent years the traditional barrel maturation of wines has evolved gradually to bigger barrels. This has resulted in a change in wine style, in that the oak character seems more integrated. By using alternative oak products combined with MOX winemakers are able to manipulate wine styles even more. The dosage at which the products are used, differs considerably. In Chardonnay wines this ranges from 1 to 3 g/litre wine or up to 20% of the barrel surface if staves are used. The wines are left on the lees mostly and stirred for a few months. In red wines usage also varies considerably. Medium to heavily toasted chips may be used for example to impart vanilla flavours to the wine without changing its phenolic character. Up to 2.5m2 staves may be used per 1 000 litres of wine, if a heavily wooded wine is required for blends. However, most winemakers use 20 to 30% of a barrel surface (ca 1.25 to 2.0m2 staves per 1 000 litres of wine). If more is used, the wood character will be excessive and unbalanced.

Various volatile compounds deriving from oak contribute to the flavour of wine. During the toasting of wood the thermal breakdown of wood polymers occurs, resulting in the desired flavour compounds. The extent of toasting has a significant effect on this. Oak lactones are probably the most important oak based flavourants, but are not always desirable. Their

concentration increases with moderate heating, but reduces with intensive heating. The vanilla and coconut flavours occurring in American oak especially, are lactone based. American oak is also more sensitive to the breakdown of heat, which probably explains why more lactones are found in it. In the case of a toasted stave one can therefore expect the exterior of the staves, which had been exposed to more toasting, to contain more lactones than the interior.

With increased toasting the oak tannins will decompose. This is especially important in the case of alternative products that do not have the same wood depth as barrel dowels.

Further heating will also break down the hemicellulose polymers in simple sugars, causing further breakdown to compounds such as furfurals that taste of caramel and impart toasted, sweet characteristics to the wine. The compounds are usually present on the surface of toasted oak. Heavy toasting of oak will also result in the breakdown of these compounds.

More heat will cause the decomposition of wood lignins, which may cause vanillin and other related compounds. Smoky flavours will only be formed once the oak is heated further.

Theoretically alternative oak products can fulfil the same function as barrels, except that the latter enable a gradual uptake of oxygen. In the case of the alternative products, this role can be fulfilled by MOX. A dosage of 1 to 2.5 ml oxygen/litre wine/month is suggested. The variation in dosage is similar to the difference in permeability of new and used barrels. MOX treatment ensures that the prominence of the oak character is softened.

The physical circumstances of oak maturation play an important role in the optimisation of the process. Temperature control is probably the most important variable in this regard. Maturation at room temperature without any control will expose the wine to unnecessary seasonal temperature variation. Where alternative oak products are applied in wine containers, the temperature will be easier to manage because the temperature of the wine itself may be used. Wine treated in this way will have more fruit and maturation potential than in the case of barrel maturation at fluctuating temperatures (Paul and Gore, 2006).

References:

Paul, R. & Gore, R. 2006. How and why winemakers use barrel alternatives to improve wine quality. Wine Industry Journal 21(5): 34 - 37.

Pregler, P. 2006. 2006 Barrel and Oak Report. Wine Business Monthly December 2006: 28 - 35.

The flavour contribution of wood to wine

Barrels have been used in the wine industry for various reasons for over two thousand years. Although ceramic vessels were intially used to contain wine, these were not sufficiently durable for transport purposes and the lack of modern-day steel or plastic meant that the obvious solution, due to its price, durability, limited porosity and structural strength, had to be wood. In the contemporary wine industry, however, the role of wood has evolved to being far more than a simple container.

The contemporary use of wood in vinification may influence wine composition in various ways. Compounds may be extracted from the wood, slow oxidation of the wine components may occur and the micro-flora in the wood, either new or used, may also play a role in the wine composition.

The nature and concentration of compounds extracted from wood are determined by factors such as the moisture content of the wood, origin, drying, toasting level and the toasting period. The best known compounds that may be extracted are the following:

Deriving from untoasted wood: Lactones with a coconut character and nonenes with a sawdust character.

Deriving from toasted wood: Vanillin with a vanilla character, eugenol with clove, guaiacol with smoke and furfural with an almond character.

Deriving from microbial action: Furfuryl mercaptan which has a coffee character.

The concentration of some compounds varies depending on the extent and period of toasting. Vanillin concentrations, for example, are low in untoasted wood, medium in medium toasted wood and lower again in heavily toasted wood as a result of degradation; the furfural concentration in wood, on the other hand, increases with increased toasting.

Due to the porous nature of wood, gradual oxidation will always occur in barrels. If long maturation occurs in barrels, oxidised products such as sherry and Madeira may therefore be expected. Since barrel maturation also goes hand in hand with time, it is obvious that chemically such wines will be more stable due to the time factor.

The porous nature of wood presents the ideal breeding ground for micro-organisms and is therefore also very hard to clean effectively. Contrary to expectations, the potential for microbiological spoilage of wines appears to be much greater in new barrels. This may be explained by the higher concentration of hydrolisable sugars and more available oxygen in new barrels.

Barrel fermentation is often employed by winemakers to ensure strong wood character, but also to allow integration of the wood and wine flavours. The alcoholic fermentation is a reductive process, however, unlike normal barrel maturation which entails slow oxidation. This may cause some wood compounds to be less prominent due to the fermentation in the barrel, because they are reduced instead of oxidised. Vanillin is a typical example. If the same wine is placed in the same barrel before or after alcoholic fermentation, the latter will have a more pronounced vanilla character than the former.

Oak is a natural product and variation in grain density, porosity and chemical composition of the wood may therefore be expected to occur. This implies that barrels are bound to differ from each other and that the problem may be solved only by using alternative wood products seeing that the manufacturing process thereof results in greater homogeneity.

Various alternative wood products are available. The basic difference between barrels and the use of alternative wood products is that in the case of the former the wood is around the wine, while in the case of the latter the wine is around the wood. Basically this is the reason why micro-oxygenation (MOX) is generally used in conjunction with alternative wood products. The contact surface of oak chips is obviously much larger than that of a wooden barrel, thereby promoting the extraction of more wood compounds. The extraction tempo of oak components from wooden chips is not always linear, however, which is why preliminary trials are recommended. The most important characteristics of oak chips compared to oak barrels are the following:

- Consistent chemical composition, particle size and product characteristics.
- Quality control in obtaining oak, production and distribution thereof.
- The cost advantage of oak chips in terms of wood influence per unit price.

(The first two characteristics are applicable in South Africa only if the supplier in question is able to confirm this in the product specifications.)

References:

Bowyer, P.K., Bompas, C. & Murat, M-L. 2007. The aromatic science of oak and oak chips. Australian & New Zealand Grapegrower & Winemaker, April 2007: 61 - 64.

The influence of toasting and particle size on the flavour contribution made by the use of altenative wood products in vinification

It is common knowledge that the toasting of barrels has a very important influence on the flavour impact of the barrels on wine. More than 200 oak based volatile components have been identified. In a previous article the contribution of certain flavour components was discussed. In the case of alternative wood products different factors play a very important role, and other physical aspects that are not applicable when using barrels, merit consideration. The size and dimension of alternative wood products differ considerably and should be taken into account, inter alia, when toasting such products.

Last year Tarac Technologies of Australia launched a new range of alternative wood products known as OakEX. This was the result of a research project to develop the best toasting practices for alternative wood products in order to create a volatile oak profile similar to that of barrels. A unique toasting process was developed for such products. Oak staves are stacked in such a way that free movement of air may occur between the staves. Warm air is used for toasting and consequently a temperature gradient occurs across the thickness of the oak staves. Seeing that temperature influences the formation of various volatile oak components, different flavourants will occur on the different levels of the toasted stave. The toasted stave is then sold as is or in the different formats of alternative products such as mini staves, cubes or chips. Alternative products are usually toasted only after the particular format has been produced. It goes without saying that there is a much larger variation in the composition of such products, compared to the method used by Tarac Technologies. Since warm air is also used for their toasting process, there is more control over the formation of the guaiacol products that impart unpleasant smokey characters. The sensorial characteristics that are usually obtained by using their products are cinnamon, spice, sweet oak and vanilla, which occur in considerably higher concentrations than in other competitive products.

A recent project aimed to:

- Determine the amount of volatile components extracted over a specific period of time.
- Determine the variation in the volatile oak profiles caused by the different toasting methods of alternative oak products.
- Determine the influence of the wood particle size on the extraction of volatile components.

The extraction period of volatile components

Oak remained in contact with wine for periods of one, two and four weeks and the extracted concentrations of the components were determined using a gaschromatograph. Most of the components were extracted during the first week and the extension of the contact period to four weeks had little effect.

The influence of toasting on flavour extraction

Different toasting methods of oak had a huge impact on the spectrum of flavour components and the concentrations thereof that are formed during toasting. Winemakers should take note of this and be aware that a standard dose of various alternative products will not have identical results.

The influence of the particle size of the product on flavour extraction

Three different particle sizes, namely powder (less than 1 mm), small chips (1 to 5 mm) and normal chips (5 to 10 mm) were investigated. The particle size has a widely divergent influence on the extraction of flavour components from oak. The origin of the oak, be it French or American, also plays a significant role and more research in this regard should be done (Obradovic and Kinley, 2007).

Taking the above into account, winemakers should realise the importance of purchasing such products according to specifications and not at random.

Reference:

Obradovic, D. & Kinley, S. 2007. Time, toast and size: Putting oak alternatives into perspective. The Australian & New Zealand Grapegrower & Winemaker, April 2007: 67 - 72.

The use of heat and water in the construction of barrels

Traditionally the construction of barrels has always involved heat and water for practical reasons. In order to obtain the shape of the staves and to ensure different degrees of barrel toasting, it was necessary to take both these physical factors into account. In due course the suppliers of barrels and alternative wood products realised that being variables, these two factors presented different combination options. By making use of these possibilities, a greater variation of barrels or alternative wood products could be obtained.

Before the construction of barrels can take place, the wood is bent by heat to shape the staves. This can be done using heat and/or water. The use of heat is a decisive factor, however, to obtain specific flavour profiles.

Heat transfer can take place by means of conduction, radiation or convection. Conduction is the transfer of heat from a warmer part of fixed matter in a single unit, alternatively fixed matter that come into contact with each other. The distribution of heat through fixed matter is therefore conduction. Obviously different materials differ in their ability to conduct heat. Metals, for example, are good conductors while wood, glass, ceramics and fluids are poor conductors. The only instance where conductivity plays a role in barrel composition, is when a specific logo is burnt onto the barrel.

Radiation is the transfer of heat from a warm to a cooler substance through the release of particles or rays. This obviously includes radiation such as alpha-, beta-, gamma- and X-rays as well as micro- and radio waves. In the case of wood preparation, only thermal radiation is important. Other than with conduction, the various components do not have to be in physical contact with each other.

Convection is the heat transfer between liquids and gases. If one portion of gas or liquid is heated, a flow process ensues between the warmer and the colder parts. The result is that the warmer and the colder portions mix to result in an even temperature.

The traditional custom of constructing barrels around an open fire is based on the heat radiation of wood. Because heat transfer in this instance occurs in straight lines, the distance between the open fire and the inside of the barrel plays a very important role. In order to allow the toasting of the wood to occur, very high temperatures have to be obtained in the fire. This explains why traditional toasting only occurs to a depth of 4 to 5 mm. To obtain a deeper toasting, the temperature on the surface has to be high enough for charring or blistering to occur. The temperature difference between various degrees of toasting is therefore minimal. At the Demptos cooperage, for example, it is 131°F for light toasting and 176°F for heavy toasting with the various degrees of toasting, medium and medium plus, in between. If barrels are not toasted, however, the wood character would be too aggressive; the toasting of wood also brings about additional flavour components that will be imparted to the wine.

In view of the fact that the toasting of barrels results from a combination of temperature and time, the control thereof will differ, with varying results, from one cooperage to the next. Over the years the large cooperages have mechanised to a certain extent, but the role of individual coopers should not be underestimated. Wood being a natural product, the wood that is used for barrels will differ and individual cooperages must do their utmost to eliminate these differences between barrels.

One of the methods that may be employed to manage the toasting process more accurately, is the use of convection. This method was patented by Tonelería Nacional. In the case of convection heating temperatures never get high enough for charring or blistering of the wood to occur. Much deeper toasting can therefore be achieved. With the aid of computer programmes different temperature-time combinations can be determined and barrels toasted according to a recipe with specific objectives. Barrels toasted in this way using warm air differ from conventional toasting and it is possible to meet the specific demands of winemakers with greater accuracy. It is also possible, however, to obtain thermal radiation by other means than an open fire, for example by using heating elements, a process which was developed by World Cooperage. Obviously this can also be controlled better than traditional toasting (Philips, 2007).

Each cooperage will most probably continue to believe that its own method produces the best barrels.

Reference:

Philips, C. 2007. Fire, Water and Oak. How Barrels are Toasted. Wine Business Monthly, May 2007: 22 - 33.

The use of high-power ultrasonics to clean and sanitise barrels

The porosity of oak barrels plays an important role in the wood maturation of wines. Without it barrels would simply impart an oak character to the matured wines without enabling the interaction between oxygen and oak components during maturation. The porosity of wood also enables the wine to penetrate the barrels to ensure a more effective use of the wood. This movement of wine also causes micro-organisms to settle in the wood and consequently the cleaning and sanitation of barrels is crucial.

Barrels have been used in the vinification process for many centuries and they come in different sizes. It is estimated that approximately seven million barrels are currently being used in wine cellars around the world. The financial impact on the production cost of wine is enormous and it is therefore important for barrels to be used as effectively as possible. In this regard winemakers are concerned about evaporation losses that occur during maturation as well as the possible microbiological contamination of barrels. Throughout the world the increasing occurrence of *Brettanomyces/Dekkera* is a major concern. Its dispersion in wine cellars may be ascribed to the use of contaminated equipment such as hoses, pumps and barrels. Much research has been done on the timely identification of the occurrence of *Brettanomyces/Dekkera*, but information on techniques to limit its distribution is scant.

During the maturation of wine in barrels, or the use of alternative wood products, cream of tartar (K-bitartrate) is precipitated on the surface and colourants, proteins, lees and other micro-organisms settle in the containers. However, some of these components are also able to penetrate the pores of the wood, and microbic-biofilms might even be formed on the surface of the wood. Due to the formation of biofilms, increased resistance to solubles and antibiotics is created. The effectiveness of sanitation procedures depends largely on the extent to which they succeed in dissolving biofilms. Acetic acid bacteria, lactic acid bacteria and yeasts are adapted to growing in a vinous environment and the growth of mould may also occur inside barrels if sufficient drying and treatment with sulphur dioxide do not take place after cleaning. Barrels infected with acetic acid bacteria or moulds are usually not suitable for repeated use, as it is extremely difficult to remove the flavours that are thus formed.

Current methods and practices to clean or sanitise barrels may be summarised as follows:

Low or high pressure cold and warm water: A variety of manual or mechanised equipment for barrel washing is currently available. Warm water at 60°C to 82°C is used in combination with pressure ranging from 680 to 2684kPa. This is usually followed by a cold water rinsing process. At the above-mentioned temperatures the soft tartrates will be dissolved, but temperatures above 85°C or steam are usually required to remove the hard tartrate deposits from barrels. Moreover, the above-mentioned temperatures will ensure limited surface disinfection only. Steam is required to disinfect the internal surface of barrels, but only to a depth of 2mm, while wine penetration occurs to a depth of 8mm.

Chemicals: Various products, including solutions of caustic soda (NaOH) or potassium carbonate may be used to dissolve the tartrates. Such treatment is usually followed by citric acid and water rinsing processes. If barrels are not reused directly after cleaning, they should be filled with sulphur dioxide gas and the bung hole sealed to prevent the growth of mould. Although ozone is occasionally used for barrel sanitation, no scientific proof regarding its effectiveness currently exists.

Shaving of barrels: Barrels may be shaved from 1mm to 3mm to remove the tartrate deposits on the inside. Even at that depth, however, not all the micro-organisms will be removed. Toasting of the shaved barrels may destroy all micro-organisms, but on the other hand such treatment might also create undesirable flavour components in the wood. The shaving of barrels will nevertheless remove toasting blisters that occasionally occur in barrels, serving as growth medium for micro-organisms.

Dry ice particle radiation: The process entails the supersonic bombardment of the internal barrel surface with small dry ice particles which remove the wine residue and tartrates from the surface. (*www.barrelblasting.com*) This being a surface treatment only, micro-organisms in the pores are not removed or destroyed.

Microwave treatment: The treatment involves the use of a combination of high pressure warm water, alkaline cleaning agents, acid solutions and microwave treatment for cleaning and disinfecting barrels. It is a time-consuming process that requires considerable infrastructure.

The influence of **high-power ultrasonics** on food processing was recently investigated. The power thus created may be used to cleanse surfaces as well as porous internal structures. This process is able to destroy micro-organisms, change particle sizes of fluids and prevent the adhesion of undesirable matter to surfaces. Application possibilities of this technique to the cleaning and disinfection of wooden barrels or alternative wood products may be summarised as follows:

- The elimination or prevention of *Brettanomyces/Dekkera* contamination or other microbiological spoilage problems.
- The effective and uniform cleaning of the surface of wooden barrels or alternative wood products such as staves.
- The advantage of the simultaneous cleaning and sanitation of oak barrels.
- The removal of colourants and tartrate excretions from the inside of barrels.

For more information about the new technique contact Andrew Tap at ayap@cavitus.com.

Reference:

Yap, A., Jiranek,V., Grbin, P., Barnes, M. & D. Bates. 2007. Studies on the application of high-power ultrasonics for barrel and plank cleaning and disinfection. Wine Industry Journal 22(3): 96 - 104.

The certification of oak products used in the vinification process

The use of wood, be it in the form of barrels or alternative wood products, causes a change in the flavour and taste profile of wines. The nature of the change is influenced not only by the wood itself, but also by factors such as natural leaching and toasting of the wood. To ensure that a measure of repeatability is obtained when using wood products, winemakers use basic specifications when purchasing wood products. Seeing that they are mostly not in a position to verify compliance with the specifications, they usually have to rely on the integrity of their suppliers. In such cases some form of certification could be beneficial.

Consumers throughout the world are increasingly demanding as regards the sustainability of natural products. They insist that the natural origin and authenticity of products be known, before considering to purchase.

It goes without saying that barrels should also comply with the above requirements. The plantations where the wood originates, the way in which the raw material is obtained and processed, are some of the basic information required to ensure the sustainability of the sources. The PEFC Council ("Programme for the Endorsement of Forest Certification schemes") is an independent, private organisation founded in 1999 by various bodies representing 15 million owners of forests in Europe. Seated in Luxembourg, it promotes the sustainable management of forests through certification by independent third parties. To prospective buyers of wooden staves and paper products, the PEFC provides a warranty mechanism as regards the sustainable management of forests.

Wine industries are obviously mostly concerned about French forests. It is absolutely essential that staves be obtained from certified forests. The origin of the wood may be obtained in one of two ways. Firstly through a percentage model based on stock control and the calculation of wood or material flow, or secondly through the physical segregation of the wood. In the first instance a business may use a PEFC logo for its products if more than 70% of its input material is of certified origin. In the case of the segregation model, material of different origin should be kept and handled apart throughout the entire production process.

Sequin Moreau was the first cooperage to qualify as an eco-certified cooperage based on the PEFC guidelines. The French oak used for their barrels is consequently certified as originating from sustainably managed forests. Furthermore a "chain of custody" certification was obtained, which enables tracking of the eventual barrel to the original forest whence it hails. Most cellars do not necessarily prefer barrels made from wood of the same origin, but rather a mixture that complements their wines. Taransaud has a similar approach whereby barrels are composed according to the wine requirement of the cellars.

The World Cooperage stave mill in France is also PEFC certified. Audits are conducted annually by Bureau Veritas, whereafter they are certified or a quality plan drawn up to enable the traceability of staves.

At this stage it is not certain whether wine consumers are concerned about the certification of the wood. However, bearing in mind their general concern about related products, this should also apply to the use of wood in vinification.

More information about PEFC certification can be obtained on the website www.pefc.org.

Reference:

Hall, L.S. 2006. Sustainable Oak Certification Guarantees Origins and Age. Wine Business Monthly, May 2006: 2 – 3.

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